POWER PLANT ENGINEERING

Established Over 30 Years

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Pioneers

IN THE COOL of the evening under the spell of Milwaukee hospitality strangers sometimes get a glimpse of popular traditions which have grown up regarding pioneers who have made an industrial center of that city.

The late Mr. Nordberg, one of the leading authorities on design and application of large steam-driven machinery occupied an enviable position not only in the community which he helped develop but also in the engineering fraternity of the world.

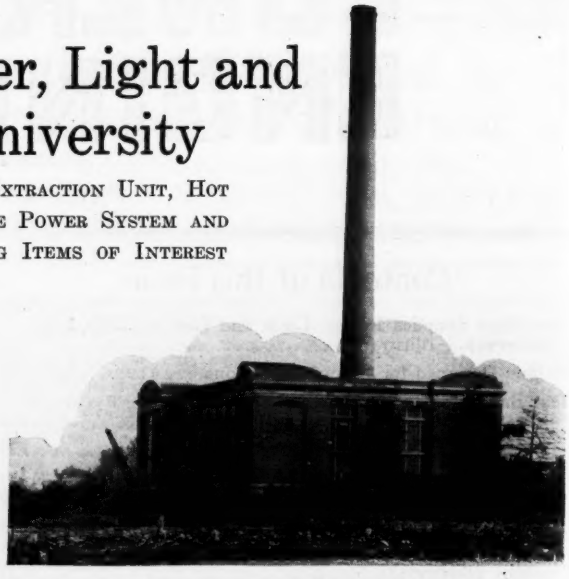
Always a leader in a new field he took pleasure in accomplishing the thing that "could not be done" and we can imagine the justifiable pride he took when the crankshaft shown above left the shops bearing the inscription "Crankshaft for Largest Uniflow Engine in America." This engine, described on page 746, a pioneer in a new field, is making engineering history, establishing a new mark for posterity.

It is difficult to imagine a more severe and exacting service than that demanded by the steel mills. Four and a half ton red hot ingots reduced to small bars or thin sheet stock in less time than a novice can think of the procedure. Loads varying from zero to a maximum, engines reversing and men sweating among flaming tongues leaping in and out amid seeming confusion. Failure means inestimable loss of time and money, a misstep death.

It is indeed an accomplishment to build a machine which can successfully master such conditions, a masterpiece of design and construction which must stand as a milestone of accomplishment.

New Plant Supplies Power, Light and Heat to Ohio State University

THREE CONDENSING TURBO-GENERATORS, ONE AN EXTRACTION UNIT, HOT WATER HEATING SYSTEM FOR BUILDINGS, 2-PHASE POWER SYSTEM AND UNIQUE ARRANGEMENT OF FAN DUCTS ARE AMONG ITEMS OF INTEREST



IN THE POWER PLANT of the average university or college, the problems encountered are usually much different from those met in the industries or in central station work. At Ohio State University, Columbus, Ohio, the services to be rendered by the power plant include both industrial and central station elements, with additional complications that are not usually found in either. The solution of these problems has been ingenious and reflects credit on the engineers in charge. The plant is not entirely finished, as one 1000-kw. extraction turbine is in process of erection at present. With this exception, however, all other equipment is as nearly in final form as it can be at the present time.

Among the interesting features of the plant, the exterior of which is shown in the headpiece, are: generation of two-phase power; operation of turbines to give proper amount of steam for hot water heating system and to produce economical power, part of the turbine exhaust going to a condenser and part to the hot water heaters; use of duplex drive on auxiliaries; special arrangements of stoker air ducts and fans; provision for continuity of service at all times on account of the two hospitals belonging to the University which must have uninterrupted light, power and heating service; double bus system for educational purposes, also for balancing of turbines. Exciters are arranged for duplex drive by both turbine and motor, for heat balance control and also for provision against shut-down. Circulating pumps for condensers are located on the river bank about 2000 ft. away from the plant and are remote controlled from the turbine room.

Of particular interest is the arrangement of main turbines in this plant, together with their condensers and the hot water heaters taking part of their exhaust steam. Two 1500-kw. turbo-generators are at present in operation, generating two-phase power and a third two-phase, 1000-kw. extraction type turbo-generator is in process of erection.

TURBO-GENERATORS FURNISH TWO-PHASE POWER

Two-phase power is used because the wiring systems for power and light in all the university buildings were originally installed for two-phase and it was considered that the cost of replacing motors and circuits would be too great to consider using three-phase. Furthermore, two-phase equipment can be obtained without undue difficulty and the electrical characteristics of such a system do not present operating difficulties of any consequence. All motor-driven auxiliaries in the power plant, therefore, are driven by two-phase motors, mostly wound for 440 v.

The double bus system has been installed for two reasons. First, it provides the engineering students with an actual commercial installation for study. Sec-

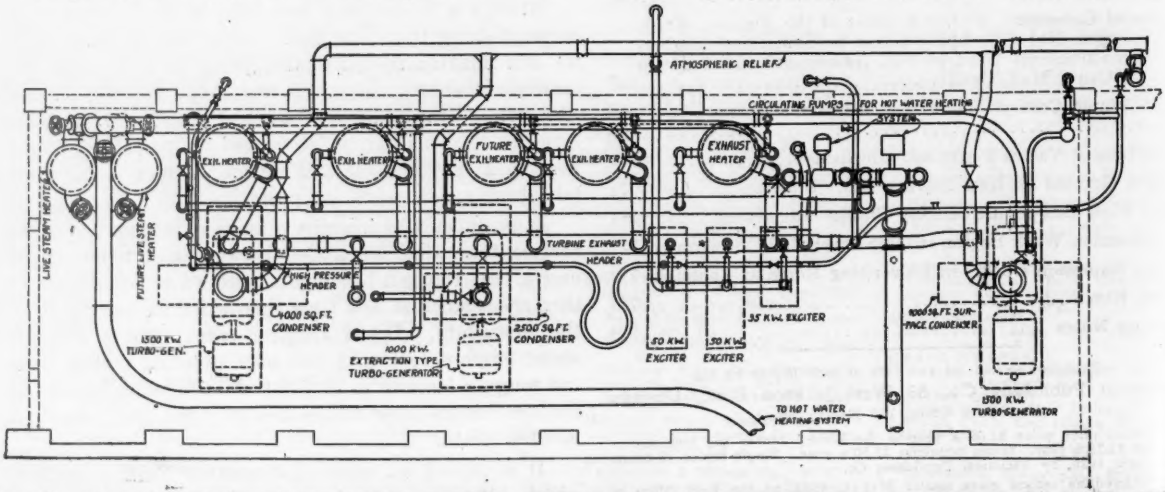


FIG. 1. PLAN OF TURBINE ROOM PIPING, SHOWING TURBINE EXHAUST CONNECTIONS TO CONDENSERS AND HOT WATER HEATERS

ond, it enables the main turbines now installed to be operated so that one machine can utilize the highest vacuum obtainable and the other can supply the proper amount of exhaust steam for the hot water heaters. The extraction turbine that is now being installed will be of great assistance in adjusting the heat balance of the plant. Operation of the turbines is so intimately connected with the operation of the heating system that they must be described together.

Two 1500-kw. turbo-generators taking steam at 185-lb. gage pressure, running at 3600 r.p.m. and generating two-phase power at 2300 v., are of standard types. They are set on structural steel foundations as indicated on Figs. 1 and 2B, slightly different from the usual practice of using concrete foundations. Ventilating air for the generators is filtered through 12,000-c.f.m. air filters in the basement. These turbines exhaust into two-pass, 4000 sq. ft. surface condensers, set below them as shown in Fig. 2B. They have the standard types of air ejectors with inter and after condensers and motor driven condensate pumps.

Circulating water for these condensers is supplied by two 4000-g.p.m., 1750 r.p.m., single-stage centrifugal pumps driven by 75-hp. squirrel cage motors and designed for the above capacity against a 30-ft. head. These pumps are located in a pump house on the bank of the Olentangy River, about 2500 ft. from the plant, but the compensators for controlling their two-phase, 440-v. driving motors are located in the turbine room and operated from one of the control boards there.

Turbine Exhaust Heats Water for Heating System

Reference to Fig. 1 shows how the hot water heaters are connected to the system. Five of these heaters are installed in the turbine room, four exhaust heaters and one live steam heater. Figure 2D shows one of the exhaust heaters, which are provided with lugs about halfway up so that they are set half above and half below the turbine room floor. Exhaust steam heaters consist of a steel shell 7 ft. in diameter and 15 ft. high, containing 570 tubes, 2 in. in diameter of No. 13 gage seamless steel tubing. These heaters are designed for steam pressure of 5 lb. per sq. in. and water pressure of 55 lb. per sq. in. and each one provides hot water for about 100,000 sq. ft. of the heating system. The live steam heater, designed for 125-lb. steam pressure, contains 345 tubes of No. 13 gage, 2 in. in diameter.

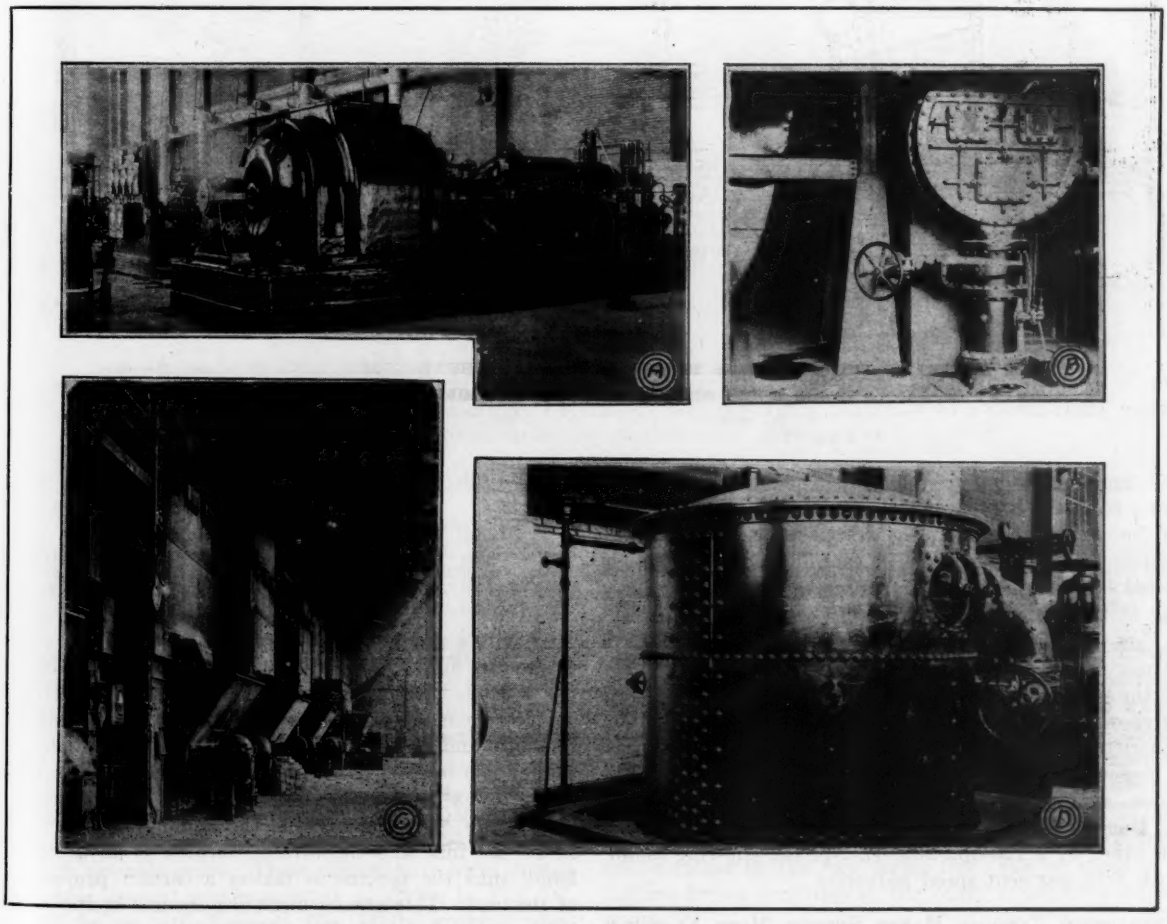


FIG. 2. MAIN EQUIPMENT FOR GENERATING AND USING STEAM AT OHIO STATE UNIVERSITY PLANT

A—No. 1 turbo-generator, of 1500-kw. capacity, generates 2-phase power. B—No. 1 unit sends part of its exhaust to this 4000-sq. ft. surface condenser. Part of the steel turbine supports and the generator ventilating air duct appear at the left. C—Steam is supplied by seven water tube boilers, six with underfeed stokers and one with chain grate stoker. D—Hot water for the college heating system is passed through this heater, one of four that use part of the turbine exhaust. In case the exhaust is not enough, live steam is added in a live steam heater of similar design.

Figure 1 shows the connections of these heaters. The connection between each turbine and its condenser is tapped off by an 18-in. pipe which runs to a steam header from which connections are made to each heater. The lead from the turbine extends over the steam header to an atmospheric exhaust pipe equipped with an atmospheric relief valve. Steam passes through the tubes of each heater and water flows outside them. Thus, by proper manipulation of the valves in these lines, part of the turbine exhaust, goes to the condenser and part to the heaters, depending on the amount of heat needed. If the hot water, after passing through the exhaust heaters has too low a temperature for the given weather conditions, it passes through the live steam heater, where enough steam at low pressure is introduced to bring the temperature up to the proper point. Condensate flows from the bottom of the heaters and is pumped up to the condensate tank to be described later. From the bottom of the steam space in each heater a connection is led back to the main condenser to prevent air binding in the heater.

It is designed for automatic extraction at 2 to 10 lb. gage and for a vacuum of 2 in. absolute, with throttle steam at 175 lb. pressure and 100 deg. superheat. For straight condensing operation, the water rates will be

Load	Lb. Steam per kw-hr.
500 kw.	16.55
750 kw.	16.15
1000 kw.	16.00

At 2 lb. gage extraction pressure, the following extraction economy is expected:

Load	Throttle Flow, lb.	Max. Extraction, lb.
500	17,500	16,300
750	24,850	23,650
1000	32,600	31,400

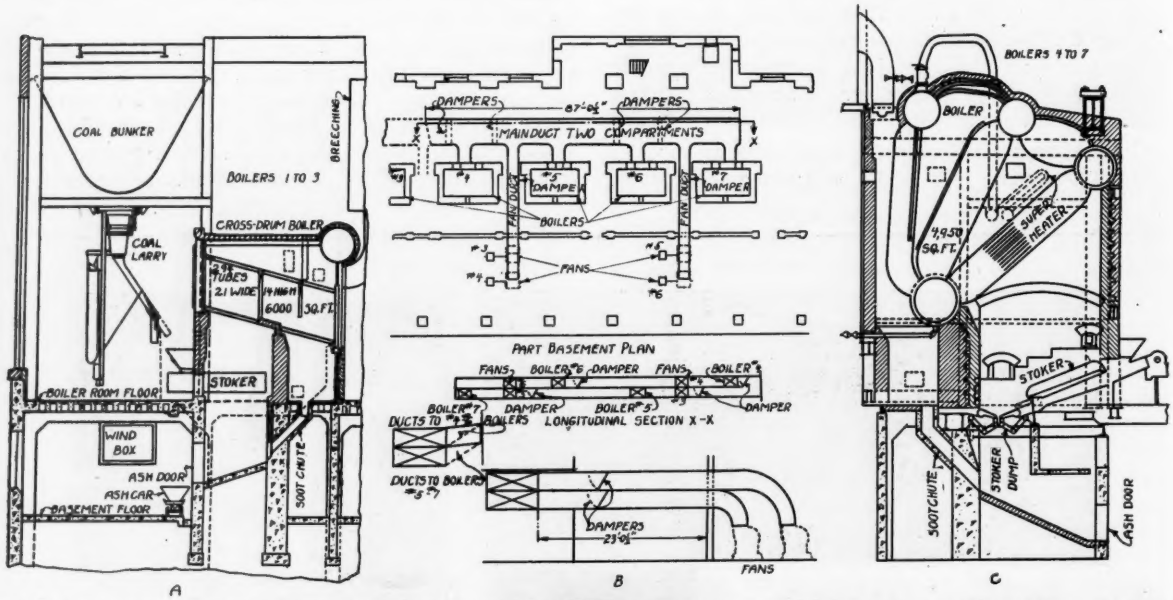


FIG. 3. A—THREE BOILERS OF THIS TYPE, EACH HAVING 6000 SQ. FT. OF HEATING SURFACE, ARE INSTALLED. B—UNUSUAL ARRANGEMENT OF FANS AND AIR DUCTS FOR BOILERS 4-7 PROVIDES AGAINST SHUT-DOWNS. C—BOILERS 4-7 ARE OF THIS TYPE, WITH 4950 SQ. FT. OF HEATING SURFACE EACH

Hot water is taken from the return main and forced through the heaters by the circulating pumps. These are on the turbine room floor and the piping connections are as shown on Fig. 1. Two 14-in. hot water circulating centrifugal pumps are used for this service. Each has a capacity of 6250 g.p.m., at a speed of 785-1175 r.p.m. against a pressure of about 55 lb. gage.

One of these is driven by a 115-hp. steam turbine, the other by a 125-hp., 2300-v., 2-phase, slip-ring motor with 33⅓ per cent speed reduction.

Extraction Turbine Makes System More Flexible

Addition to the system of the 1000-kw. extraction turbine with its 2500-sq. ft. surface condenser, now under erection, will give even more flexibility to the above system. This unit is a 6-stage, 1000-kw., 2-phase, 60-cycle, 2300-v., 0.80-p.f. machine.

At 10 lb. extraction pressure:

Load	Throttle Flow, lb.	Max. Extraction, lb.
500	20,100	18,600
750	28,500	27,000
1000	37,100	35,600

Exciters are separately driven, the two main exciters having duplex drive for heat balance control. Number 1 exciter is a 50-kw., 125-v., d.c. generator, driven at 1750 r.p.m. by a single-stage turbine on one end of its shaft and a 75-hp. motor on the other. Number 2 exciter is a 50-kw., 125-v., d.c. generator driven at 1200 r.p.m. by a three-stage turbine and a 75-hp. motor. To operate one of these sets, the motor switch is kept in all the time and the turbine throttle is adjusted by hand until the turbine is taking a certain proportion of the load. This arrangement also insures exciter service in case of electrical troubles on the motor circuits. A third exciter of 35 kw. capacity, 125 v., is also provided for standby service. This is driven at 3600 r.p.m. by a steam turbine. Figure 6 shows the No. 1 exciter.

In the University buildings and laboratories, there are a few d.c. motors, storage batteries and other d.c.

equipment, and, to provide for this, a motor generator set is installed in the turbine room. This is a 25-kw., 110-v., d.c. generator driven at 1750 r.p.m. by a 440-v., 2-phase, 60-cycle motor.

Boilers are of Two Types, with Several Types of Stokers

Steam is supplied for the above-mentioned units by seven water tube boilers of two types, as shown in section on Fig. 3. Three of these boilers, Nos. 1, 2 and 3, are cross drum boilers of 6000 sq. ft. of heating surface each. The others, boilers 4 to 7, are of the V-type, as shown. Boiler No. 1 is fired by a type A-C heavy duty steam-actuated 6-retort underfeed stoker; No. 2 is also fired by a Class 9 underfeed stoker, with grate surface as noted on the list of equipment. Boilers are blown into a reinforced concrete, brick lined blowoff tank 7 ft. in diameter and 8 ft. deep, just outside the boiler house. Figure 4D shows the control boards of two of the boilers.

These carry boiler meters of the steam-flow, air-flow type, draft indicators and recorders for air pressure, and superheated steam. Controllers for the stoker and fan motors are also shown. On account of the necessity for preventing shutdowns, caused by the hospital load, stoker and fan controls are provided with duplicate electrical circuits, so that in case of trouble with one circuit the boilers can be kept in operation. A master pressure gage is installed in the boiler room.

Boilers 4 to 7 are equipped with home-made water

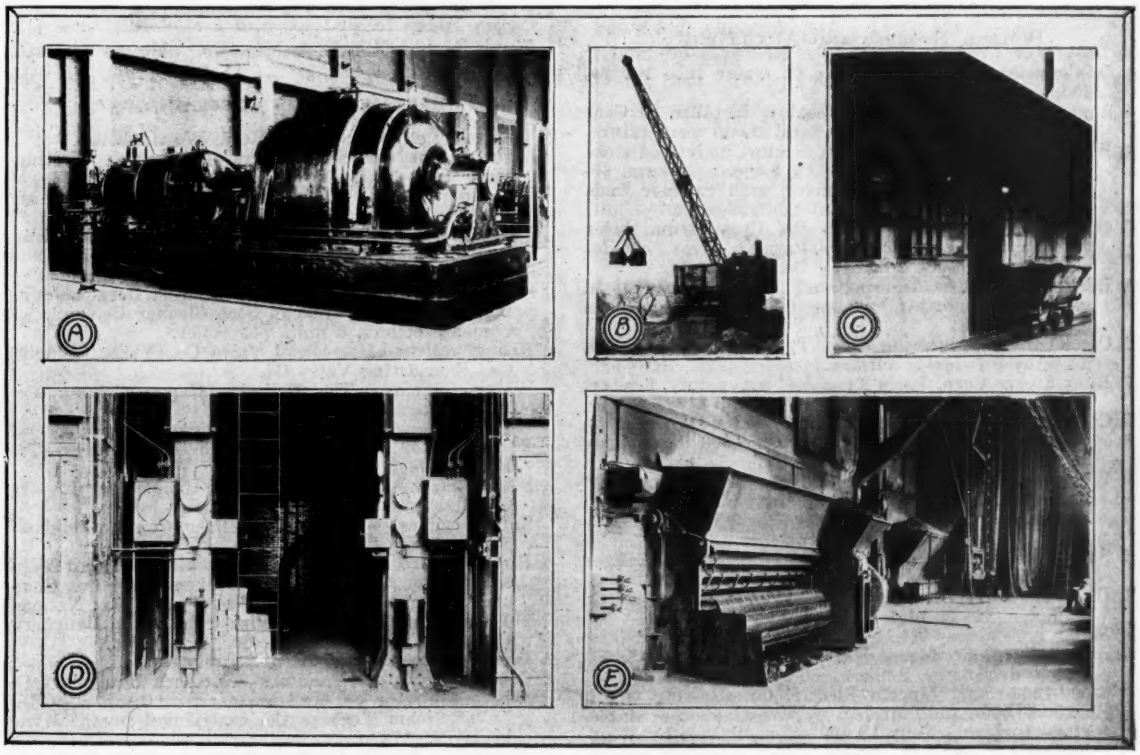


FIG. 4. DETAILS OF BOILER AND TURBINE ROOM EQUIPMENT AT OHIO STATE UNIVERSITY

A—No. 3 main turbine is a duplicate of No. 1. B— Locomotive crane handles stored coal from pile to crusher. C—Specially designed roller doors are installed on ash pits, from which ash is taken to yard pit by industrial car. D—Each boiler has equipment of steam-flow-air-flow meter, air pressure and steam temperature recorders, with fan and stoker controllers mounted beneath them. E—Close-up of boilers 1-3, showing draft indicators and weigh larry.

of 12½ by 9 ft. Number 3 is fired by a 10-ft. by 13-ft. chain grate stoker, driven by a 3-speed, 440-v., 2-phase motor.

Boilers 4 to 7 were installed more recently, having been purchased with their stokers and some auxiliaries from the government. These have 4950 sq. ft. of surface each and are fired by 5-retort Type DDN-17 underfeed stokers, driven by 3-speed squirrel cage motors through rawhide gears. These stokers have hand dumps and their general arrangement is as shown in Fig. 3C.

All boilers are designed for 200-lb. working pressure, but the normal operating pressure is 185 lb. Boilers 4 to 7 are equipped with superheaters to give a total steam temperature of 575 deg. F. Boiler No. 3 is also equipped with a superheater. Standard types of blowoff valves, water columns and soot blowers are installed backs through which water flows from the condensate tank, to be described later, to the feed water heaters. Boiler 3 is also equipped with side wall coolers; water from the city water supply goes direct to these, whence it goes to the two domestic hot water heaters for building hot water service. These heaters, installed in the turbine room basement have capacities of 12,000 and 15,000 gal. per hr. respectively. Two booster pumps are installed in the city water line; one of these is a turbine-driven centrifugal, the other a duplex plunger pump.

For circulating domestic hot water to buildings, two pumps are installed. One is a 3-in., 4-stage, turbine-driven centrifugal, the other a 3-in., 3-stage centrifugal, driven at 1750 r.p.m. by a 20-hp. motor.

All exhaust steam from auxiliaries is led to the feed

Principal Equipment at Ohio State University Power Plant

Coal Handling

2 Ohio Locomotive Crane Co. locomotive cranes, one 15 t. one 20 t.
1 Jeffrey Mfg. Co. single roll coal crusher—capacity, 50 t. an hr. driven by belt from 20-hp., 2-phase, 440-v. motor.
1 Jeffrey Mfg. Co. bucket elevator.
1 Robins Conveying Belt Co. belt conveyor over coal bunkers with Robins automatic belt tripper.
Coal bunkers, 1200-t. capacity, installed by Brown Hoisting Machy. Co.
1 Elcon Engineering Co. motor-operated weigh larry, driven by 2-speed motor.
1 Weigh larry, hand-operated, Brown Hoisting Machy. Co.
Coal-handling equipment installed by Elcon Engineering Co. except elevator and locomotive cranes.

Boilers, Stokers and Auxiliaries

4 D. Connelly Boiler Co. 4950-sq. ft. water tube boilers, 200-lb. max. working press.
4 Superheater Co. Elesco superheaters installed in Connelly boilers to give 575-deg. total steam temperature.
4 Westinghouse Elec. & Mfg. Co. 5-retort underfeed stokers, Type DDN-17. Driven by 3-speed, 2-phase, 60-cycle, 440-v. Louis Allis motor with rawhide back gears. Controller, Industrial Controller Co.
3 6000-sq. ft. Babcock & Wilcox Co. Cross drum water tube boilers designed for 200-lb. max. press., one including a Babcock & Wilcox Co. superheater.
1 Riley Stoker Corp. Harrington Stoker, 10-ft. by 13-ft. grate surface, driven by 3-speed, 2-phase, 440-v. Louis Allis motor.
1 Combustion Engineering Corp. Type E stoker, Class 9, 12½ by 9-ft. grate surface.
1 Riley Stoker Corp. Jones Type A-C heavy duty, 6-retort stoker.
2 Cochrane Corp. V-notch metering feed water heaters, one 100,000 lb. an hour and one 250,000 lb. an hour capacity.
3 Wheeler Cond. & Eng. Co. Alberger 4-in. centrifugal boiler feed pumps; capacity, 360 g.p.m. Two pumps, 3-stage; one, 4-stage, driven at 2600-3600 r.p.m. by Alberger-Curtis single-stage turbines.
1 American Steam Pump Co. Marsh Simplex plunger pump for emergency boiler feed service.
1 H. R. Heinicke, Inc., radial brick chimney, 9½ ft. in diameter, 240 ft. high from ground.
Boiler breechings—Nicklaus Boiler Works.
6 Buffalo Forge Co. forced-draft stoker fans. One 55,000-c.f.m., driven by 2-phase, 60-cycle, 75-hp., 2300-v., 600-1200-r.p.m. Lincoln Electric Co. slip-ring motor. One 35,000-c.f.m., driven by Westinghouse single-stage turbine. Four 18,000-c.f.m., driven by Westinghouse 1750-r.p.m., 30-hp., 440-v. slip-ring motors.
1 Greene Fuel Economizer Co. 18,000-c.f.m. fan, driven by Terry steam turbine.
1 Permutit Co. Zeolite water softener. Two tanks of 48,000-gal. capacity each per 24 hr.

Turbines, Condensers and Auxiliaries

2 Allis-Chalmers Co. 1500-kw., 0.80-p.f., 3600-r.p.m., 2-phase, 2300-v., 60-cycle turbo-generators. 185-lb. throttle pressure.
1 General Electric Co. 1000-kw. extraction type turbo-generator now under erection. Type F, 6-stage, 2-phase, 60-cycle, 2300-v., 0.80-p.f., 175-lb. throttle pressure, 100-deg. superheat, 2-in. abs. back pressure; automatic extraction at 2 to 10-lb. gage.
2 Reed Air Filter Co., Inc.,12,000 c.f.m. air filters for generators, 15 filter units each; capacity, 800 c.f.m. per unit.
1 Elliott Co. 4000-sq. ft., 2-pass surface condenser, duplicate single-stage air ejectors, after condenser Elliott condensate pump driven by G. E. motor.
2 C. H. Wheeler Mfg. Co. 2-pass surface condenser. One 4000-sq. ft., one 2500-sq. ft. Each has two 2-stage Radojet air pumps with inter and after condensers. Wheeler condensate pumps driven by G. E. motors.
1 Westinghouse Elec. & Mfg. Co. 50-kw., 125-v., d.c. generator, driven by Westinghouse steam turbine on one end and 75-hp., 1750-r.p.m. Westinghouse motor on other. Clarke Licensed Duplex drive.
1 General Electric Co. 50-kw., 125-v., d.c. generator. Clarke Licensed Duplex drive, using 3-stage, 1200-r.p.m. G. E. turbine on one end, 75-hp. G. E. motor on other end.
1 General Electric Co. 35-kw. exciter, 125-v., d.c. generator driven at 3600 r.p.m. by G. E. Curtis steam turbine.
1 Westinghouse Electric & Mfg. Co. m-g set; 25-kw., 110-v., d.c. generator driven by 440-v., 1750-r.p.m. motor. Direct current for building service.
2 Worthington Pump & Mach'y Corp. single-stage, 4000-g.p.m., against 30-ft. head, condenser circulating water pumps driven at 1750 r.p.m. by 75-hp. G. E. Co. squirrel cage motors.
4 Westinghouse E. & M. Co. transformers, 100 kw. each, 2300/440-v.
1 Westinghouse Electric & Mfg. Co. main switchboard, 18 panels.

Accessories and Miscellaneous

2 Voltage regulators: 1 G. E., 1 Westinghouse.
Miscellaneous electrical meters—G. E. Co., Westinghouse E. & M. Co.
Recording therm. gages and meters for steam, air, water, etc.—The Bristol Co., Bailey Meter Co.
Pipe Covering—Keasbey & Mattison sponge felted asbestos, Johns-Manville sponge-felted asbestos and 85% magnesia.
Soot blowers—Diamond Power Specialty Corp. units on B. & W. boilers. Vulcan Soot Cleaner Co. units on Connelly boilers, 6 units per boiler.
Blowoff valves—Homestead Valve Co., Yarnall-Waring Co., Everlasting Valve Co.
Water columns — The Reliance Gauge Column Co., Wright-Austin Co.
Boiler meters, draft indicators—Bailey Meter Co.
Recorders for air pressures, steam temperatures—The Bristol Co.
Steam gages—The Ashton Valve Co., Ashcroft Mfg. Co., Ashton master pressure gage.
Safety valves — The Lunkenheimer Co., Consolidated Safety Valve Co.
High-pressure steam valves and piping, Edward Valve & Mfg. Co., Crane Co., The Lunkenheimer Co., Chapman Valve Mfg. Co., The Wm. Powell Co., National Valve & Mfg. Co., Power Piping Co., M. J. Daugherty Corp., Shaw-Kendall Eng. Co.
3 Pump governors—Northern Equipment Co.
2 Copes feed water regulators—Northern Equipment Co.
Alberger ejector on condensate return tank, also DeLaval Steam Turbine Co. centrifugal pump, driven by 10-hp., 1740-r.p.m. motor.
Richardson-Phenix turbine oil filters—S. F. Bowser & Co., Inc.
2 Worthington Pump & Mach'y Corp. Laidlaw air compressors: one 200-c.f.m., belt-driven by 37.5-kv.a., 440-v. G. E. synchronous motor; one 600-c.f.m., belt-driven by 125-hp., 900-r.p.m., 2300-v. slip-ring motor.
3 Atmospheric relief valves in turbine exh., 2 Edward Valve & Mfg. Co., 1 Schutte and Koerting Co.
2 City water booster pumps: one Alberger centrifugal, driven by Terry steam turbine; one Worthington duplex plunger.
1 Morgan Engineering Co. 30-t. turbine room crane.
5 Heaters for hot water heating systems, designed by plant engineers, built by Ames Iron Works.
2 DeLaval Steam Turbine Co. 14-in., 6,250-g.p.m. circulating pumps on hot water heating system. One driven by 115-hp., 1125-r.p.m. DeLaval turbine; one driven at 1175 r.p.m. by 125-hp., 2300-v. G. E. slip-ring motor with 33⅓-per cent speed reduction.
2 Croll-Reynolds Engineering Co. domestic hot water heaters, one 12,000-g.p.h., one 15,000-g.p.h.
1 D'Olier Engineering Co. centrifugal pump on domestic hot water system, 3-in., 4-stage, driven by Terry steam turbine.
1 Wheeler Cond. & Eng. Co. Alberger 3-in., 3-stage centrifugal pump on domestic hot water system, driven by 1750 r.p.m., 20-hp. Westinghouse motor.

water heaters. Condensate from various heaters and steam traps and also from the small amount of steam heating system installed in a few of the university buildings, is brought back through suitable traps and oil separators into a tank in the turbine room basement. A steam jet air ejector creates a partial vacuum in this tank and a 10-hp., motor-driven centrifugal pump forces this condensate up to a condensate storage tank installed behind the boilers, whence it goes to the feed water heaters.

All make-up water for the boilers is taken direct from the city water mains and passed through a zeolite water softener, which has two tanks with a total capacity of 96,000 gal. per 24 hr. It is then sent to the feed water heaters. Two of these heaters are installed directly behind boilers 1 and 3. One of these heaters is a V-notch metering heater of 100,000 lb. an hour capacity, the other of the same type but of 250,000 lb. an hour capacity. These give a feed water temperature of about 200 deg. F.

Fan Ducts are Arranged to Prevent Shut-Down

One of the most interesting items in the boiler house is the arrangement of the stoker fans and fan ducts. No induced draft fans are installed, the flue gas being removed by a radial brick chimney, as shown in the headpiece, 9½ ft. in diameter inside and 240 ft. high from the ground. Forced draft fans are installed in the turbine basement, since there was no room in the boiler room basement for them on account of the construction of boiler settings as shown. Boilers 1 to 3 are served by three fans. One of these, of 18,000 c.f.m. capacity, is the right size for one boiler, the second, of 35,000 c.f.m. capacity, will serve two boilers and the third, of 55,000 c.f.m. capacity is big enough for three boilers. The air ducts are arranged with suitable dampers so that any combination of these fans can be used on the first three boilers. In normal operation this duct is entirely closed off from the duct for boilers 4 to 7, which is shown in Fig. 3B.

These four boilers are served by four 18,000-c.f.m., motor-driven fans, arranged as shown. Reference to the diagram, Fig. 3B, shows how, by manipulation of the dampers, any boiler in this group can be operated from one of the other fans in case its own fan has to be shut down. This arrangement is designed to give flexibility and to reduce the possibility of interruptions in service.

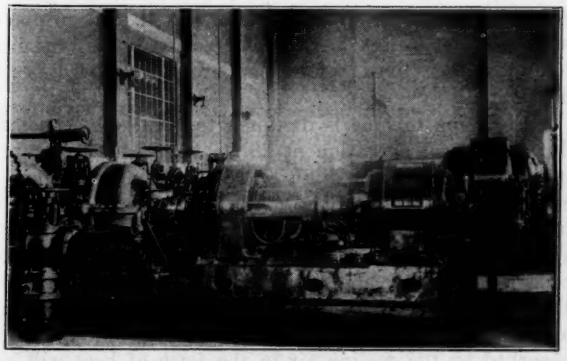


FIG. 6. MAIN 50-KW. EXCITERS HAVE DUPLEX DRIVE BY TURBINE AND MOTOR TO GIVE HEAT BALANCE CONTROL

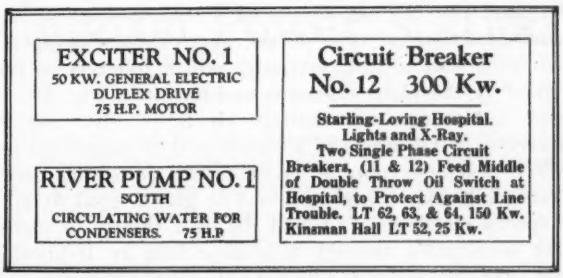


FIG. 5. LABELS LIKE THIS ON EVERY SWITCH OR CONTROL HELP OPERATOR

Feed water is supplied to the boilers by three centrifugal pumps, one 4-stage and two 3-stage units of 360 g.p.m. capacity each. These are driven at 2600-3600 r.p.m. by single-stage steam turbines. For emergency boiler feed service, a simplex plunger pump is installed.

Coal and Ash Handling Equipment

Coal used at the Ohio State University plant is mostly Hocking Valley coal with a heat content averaging between 10,500 and 11,000 B.t.u. per lb. At present coal is now dumped in a storage pile at the rear of the plant, from which it is reclaimed by a locomotive crane, shown in Fig. 4B. Plans are now being made for a coal storage space of about 25,000 t. capacity on the bank of the Olentangy River, about 2000 ft. from the plant, and the coal will be stored there under water.

Coal from storage is loaded by the locomotive crane into a hopper in the roof of the crusher house at the south end of the boiler room. The bottom of this hopper has a plate feeder, which feeds the coal into a single-roll crusher with a capacity of about 50 t. an hour. The crusher delivers the coal to a bucket elevator which raises it to the level of the bunkers and dumps it onto a belt conveyor running over the bunkers and it is then distributed to the latter by automatic tripper. Bunkers are of reinforced steel-cement construction with a capacity of about 1200 t. From the bunkers, the coal is loaded into a weigh larry, shown in Fig. 4E. This is motor-actuated by a 1½-hp., 440-v., 2-speed motor. A hand-operated weigh larry is also installed but the motor-driven unit is used most of the time. As will be noted, from Fig. 4E, the hopper of the chain grate stoker interferes with the larry spout, so a special swinging extension had to be provided on the spout so it would go past.

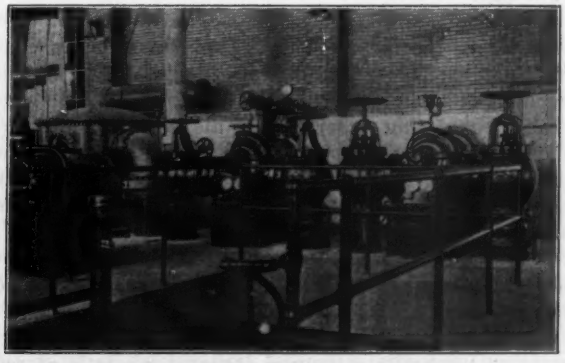


FIG. 7. TWO CENTRIFUGAL PUMPS CIRCULATE HOT WATER FROM THE EXHAUST AND LIVE STEAM HEATERS THROUGH THE BUILDING HEATING SYSTEM

Ash from the stokers and soot from the soot chamber drop into the ash hopper as shown in Fig. 3. Instead of the usual type of ash gate on these hoppers, the front wall is built vertically and a roller door, designed by the plant engineers and shown in Fig. 4C, is used. Although not entirely air tight, this door is nearly so. It consists of a cast-iron door supported by roller bearings running on a track above the door, frame and door being machined to give a good fit and a special clamp used to hold the door tightly in place. Ash is emptied through this door into an industrial car, as shown, which is wheeled out by hand and dumped into a large concrete pit in the yard. From here it is removed by the locomotive crane for filling, walks, drives and other uses about the university grounds.

For compressed air supply at about 80 lb. pressure, for miscellaneous work about the power plant and shops, two air compressors are installed, one of 200 c.f.m. capacity belt driven from a 37.5 kv.a., 400-v., synchronous motor, used in power factor correction, the other a 600 c.f.m. compressor belt driven from a 125-hp., 900 r.p.m., 2300-v., slip-ring motor with 50 per cent speed reduction.

Switchboard and Control Boards

In the turbine room is a well-equipped 18-panel switchboard carrying all necessary meters, oil switches, circuit breakers and knife switches. Oil switches are of the double-throw type to permit throwing the various units from one bus to the other of the double-bus system mentioned previously. Behind the main switchboard is another board used to give further division of circuits for testing and instructional purposes.

On all switchboards, an interesting method of labeling all switches is used. Cards giving full information about the circuits, amount of power and operations controlled by each switch are printed in large type, as shown in Fig. 5, and placed in the name plates. These occupy more room than the cards usually found on a switchboard, but on account of the multiplicity of circuits in this plant, it has been found that they are worth the trouble. Cards of this type are too often mere scraps of paper, bearing an illegible penciled scrawl, and although it is a small point, the use of cards like the above may sometimes prevent serious errors.

Transformation of the generated power is effected by two banks of two transformers, each bank rated at 200 kw. These transform from 2300 v. to 440 v. for auxiliaries in the power plant and for some of the nearby buildings.

Various control boards for the auxiliaries are also mounted in the turbine room. One board carries controls for exciters 1 and 2, for the hot water system circulating pumps, and remote controls for the condenser circulating water pumps at the river. An instrument board carries recorders for outside temperature, incoming and outgoing temperatures of hot water to the heating systems; fluid meters for outgoing live steam to buildings, and steam flowing to the turbines; recorders for superheated steam temperature, incoming and outgoing condenser water, exhaust steam to heaters, and boiler pressure.

As shown in the illustrations, the power plant presents an unusually attractive appearance. It is of red brick with stone trim, and concrete floors. The turbine room has a wainscoting of white tile, the walls are practically all windows with steel sash and the ceiling has been made of metal lath and plaster, giving a flat ceiling underneath the roof trusses.

Operation of the plant is in direct charge of T. D. Banks, plant engineer under William C. McCracken, chief engineer and superintendent of buildings at Ohio State University. Much of the general design of the power plant was done by these men as well as some of the interesting details of equipment and operation described above. The results obtained with this plant have been most satisfactory and the solution of many of the engineering problems most ingenious. We are indebted to Mr. Banks and Mr. McCracken for data, blueprints and co-operation while visiting the plant.

Turbine Designed for Special Conditions

Desert Plant of American Trona Corp. Expected to Reduce Power Costs

MANUFACTURERS of modern power plant equipment are often called upon to meet unusual requirements of industrial or geographical conditions. The General Electric Co. is now building a 3600 r.p.m., 1875-kv.a., 480-v., 3-phase, 60-cycle turbo-generator set to meet the requirements of the American Trona Corp. whose plant is located near a large dry salt lake in the Mohave Desert of California.

Large quantities of steam are used for triple effect evaporators in the process of separating the salt into its constituent parts—borax, potash and other chemicals. The new turbine will receive saturated steam at 150 lb. and operate against a back pressure of 28 lb. kept constant by a regulator control acting through the governor synchronizing equipment.

Exhaust steam is fed to a common header which receives the exhaust of the steam-driven pumps and other equipment as well. The turbine, therefore, acts as a reducing valve and at the same time obtains from the process steam the available power between boiler and process pressures. Additional power required by the plant is furnished by the Southern Sierras Power Co. from their hydro-electric system. Formerly the power company supplied all the power used so the new unit should effect a considerable saving.

As the American Trona Corp.'s equipment will be in synchronism with that of the power company, the sudden loss of the system load might cause dangerous overspeeding of the turbine and, to prevent this, the emergency governor tripping mechanism will be equipped with a cutout switch to throw the generator off the incoming power lines before dangerous overspeeds can develop.

While the turbine is designed to give best economy during normal operation at 28 lb. gage back pressure, it will also operate at high economy during emergency condenser operation, thus conserving water—the most important consideration of the development. Mountain spring water will be used in the surface air cooler which cools the generator and this water, after passing through the cooler, will be fed to the boiler feed water heaters and thence into the boilers. Thus, the generator losses absorbed by the cooling air in the form of heat will be transmitted to the cooling water and conserved.

Heat Balance at the Sterlington Power Station

EXTRACTION FEED-WATER HEATERS, HIGH PRESSURE EVAPORATORS WITH HIGH HEAT-LEVEL CONDENSERS AND HOUSE TURBINE FORM SIMPLE, RUGGED AND INEXPENSIVE SCHEME. BY W. S. JOHNSTON

STERLINGTON POWER STATION of the Louisiana Power Co. is located 20 mi. north of Monroe, La., on the east bank of the Ouachita River and in the heart of the Louisiana natural gas field. The initial installation consists of two 15,625-kv.a., 80 per cent power factor, combination impulse and reaction type steam turbo-generators, shown in Fig. 1, supplied with steam at 300 lb. gage by four 13,170-sq. ft., cross-drum water-tube boilers fired by natural gas. The present building has a ground floor area of 24,230 sq. ft.; on the basis of 30,000 kw. this gives 0.81 sq. ft. of area per rated kw. made up of 0.33 sq. ft. per kw. for the boiler room and 0.48 sq. ft. per kw. for the turbine room, or 1.23 kw. installed per square foot of station ground area. Of the total plant, a ground floor area 25 ft. by 36 ft., equivalent to two bays, is devoted to the feed-water heating and heat balance equipment, as shown in Fig. 2, arranged so as to fill completely the space from the turbine room floor to the lower chord of the roof trusses over the auxiliary bay, a distance of 40 ft. This space is located at the south end of the plant and of course does not include the extraction heaters which are placed on a deck below the turbine room floor and adjacent to the turbines so as to require the shortest possible steam connections. The position of these heaters is indicated on Fig. 3, a sectional elevation of the turbines.

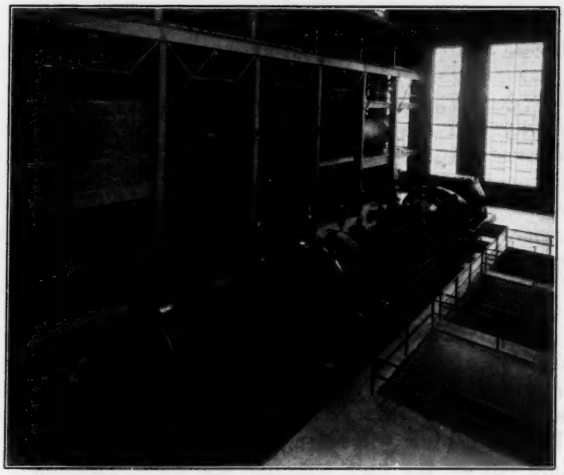


FIG. 1. FEED-WATER AND HEAT BALANCE EQUIPMENT OCCUPIES SPACE ON MAIN TURBINE ROOM FLOOR

Eight feet below the floor of the auxiliary bay is another floor upon which are located the make-up pumps. The space between these two floors also constitutes a pipe tunnel. Beneath the tunnel is a vaulted cold well, 9 ft. deep, which functions both as a surge tank and for storage capacity. The building structure in these two bays below the ground floor is entirely of concrete, while above it is of structural steel and subway grating. The general arrangement of the equipment and the relation of its location to the balance of the station is clearly shown in the accompanying diagrams and photographs.

In laying out the feed-water scheme for the Sterlington Station, the writer endeavored to select an arrangement at once simple and rugged as well as inexpensive, yet providing all those features that would insure the best overall economy of the plant. No equipment was seriously considered that would not earn its own fixed charges and, in view of the cheap fuel available in the gas field, this one consideration of earning fixed charges was a problem in itself. Fortunately, in laying down the fundamental design of the station, it was decided to use electrically-driven auxiliaries but to include a house turbine of sufficient capacity to carry the essential

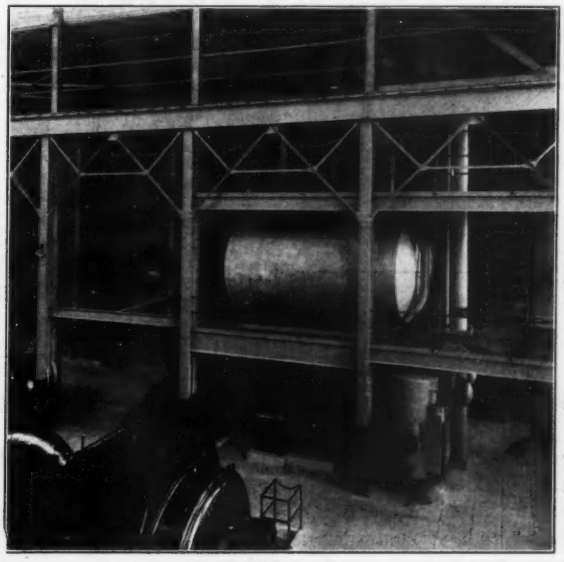


FIG. 2. FEED-WATER HEATERS ON GALLERY, WITH EVAPORATORS AND BOILER FEED PUMPS BELOW ON MAIN FLOOR

auxiliaries. The only other source of exhaust steam is two turbine-driven boiler feed pumps; a motor-driven boiler feed pump is also provided, giving three feed pumps. In general, a feed-water heating scheme can be very easily planned for high loads but at low loads on the station the amount of condensate may not be sufficient to condense all the auxiliary exhaust steam, resulting in a loss of economy at such loads unless there is a flexible arrangement of electrically-driven auxiliaries. Furthermore, the presence of auxiliary exhaust steam at any load may be an uneconomical factor as it will obviate the use of extraction steam, which, in almost any central steam station, is the cheapest steam to use for feed-water heating, provided the bleed points are properly chosen. If, an arrangement can be worked out, however, whereby exhaust steam can be reduced to a minimum comparable with continuity of service and preference given to the use of extraction steam, then the best probable economy is secured. The writer did just this in designing the heat balance scheme for Sterlington and added a feature whereby the amount of extraction steam used was closely regulated depending upon

the amount of auxiliary exhaust steam available to be condensed.

The turbines purchased were designed to allow for bleeding steam at four points. The lowest point was without a doubt to be used as, at any load on the turbine, the expected temperature of the steam would not exceed 173 deg. F. at the lowest vacuum of 27½ in., which it was assumed might be all that could be secured in summer time with 90-deg. water when passing approximately 27,000 g.p.m. of circulating water through the 20,000-sq. ft., two-pass, surface condenser. A similar examination of the next highest bleed point also indicated that it could be used in the general scheme if some means were incorporated to regulate the amount of extraction steam bled. The remaining two bleed points were both at too high temperatures to permit of being used on a low-pressure system.

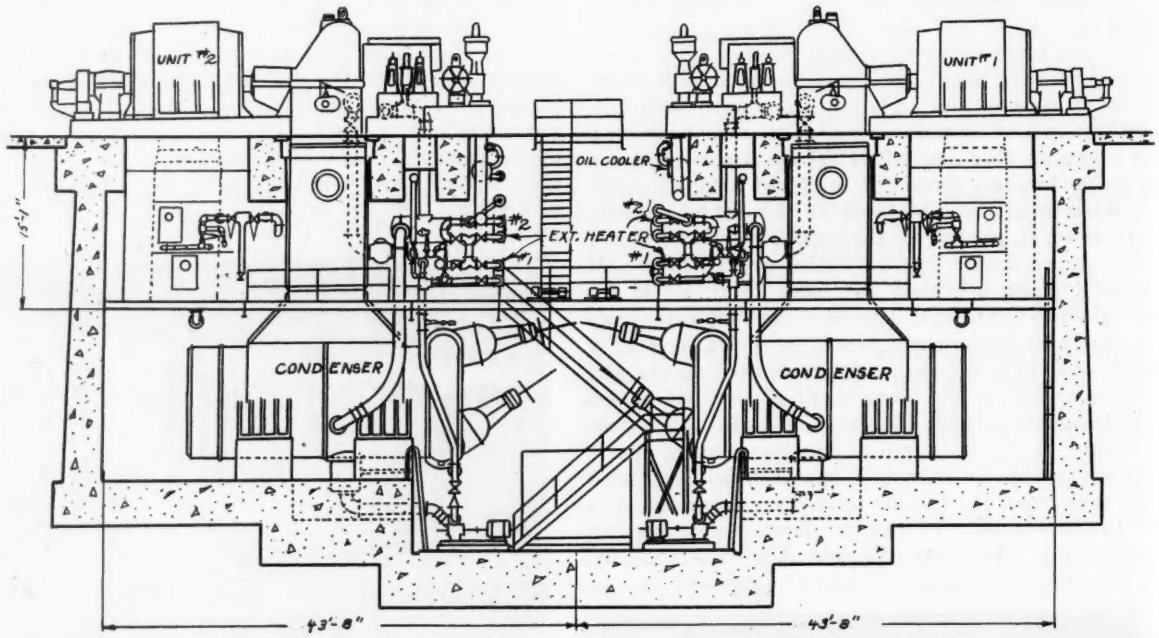


FIG. 3. ELEVATION OF THE TWO 15,625-KV.A. TURBO-GENERATORS, SHOWING EXTRACTION HEATERS AND CONDENSERS

High-Pressure Evaporators Supply Make-Up and Form Important Link in Heat-Balance Scheme

At this juncture in the design, it became necessary to decide what method should be used to purify the make-up water required, the raw water available being entirely unsuited for boiler feed purposes because of its sodium chloride content. After careful consideration of the many hot and cold processes available and numerous studies of the various methods in which evaporators might be incorporated, a decision in favor of the latter was reached. The primary function of evaporators is, of course, to supply the distilled make-up but in the Sterlington Plant they fulfill a dual function, as they also have a place in the heat balance. Many schemes of working them into the cycle were analyzed and from the viewpoint of simplicity of layout, flexibility of operation, and their economic value in the general scheme, high-pressure evaporators, Fig. 5, were selected; i. e., steam supplied to the evaporators is taken from the high-pressure system rather than from the turbine through a bleed connection or from the auxiliary exhaust system. The vapor generated in the evaporators is condensed in high-heat-level surface condensers, Fig. 5, the condensing medium being the boiler feed water. Hence, the capacity that may be developed by the evaporators is limited only by the amount of water used in the feed system. This arrangement affords boiler feed water at temperatures considerably above the customary 210 deg., the actual feed temperature varying between 250 and 260 deg. F., depending on the amount of water in service. Of course, this temperature is maintained by automatic equipment closely regulating the numerous factors involved, including the temperature of the water to the high-heat-level condensers, the amount of vapor generated and the pressure of the steam to the evaporator.

Outline of the Regenerative Cycle

It might be well at this point to describe briefly the features of the regenerative cycle in use at Sterlington and to trace the course of the water from the condensers to the boilers through the heat exchange apparatus. This description will refer to but one unit; the plant is laid out on the unit principle and there are now installed two units, but reference will be made to points at which the two units are interconnected by the valves. Figure 4 is a diagram of the layout for unit No. 1.

From the hot well a 10-in. line is the common suction connection for two duplicate condensate pumps, each pump being of 500-g.p.m. capacity, providing 25 per cent excess capacity for the maximum turbine water rate at 27½-in. vacuum. The pump drives are 30-hp., 2300-v., a.c., constant speed motors. From the pumps the condensate passes through the intercoolers and after-condensers of the twin compound steam jet ejectors on the deck overhead. The ejectors use a constant quantity of steam, 650 lb. per hour for each compound ejector, at 175 lb. pressure, this steam being taken from the aux-

iliary high-pressure system through pressure reducing valves. An emergency steam connection is also provided directly off the main turbine lead.

From the after-condenser the condensate is passed through No. 1 extraction heater and then into No. 2 extraction heater. These two extraction heaters are duplicates and are of the floating head type. Each contains 650 sq. ft. of heating surface consisting of ¾-in. Muntz metal tubes arranged as four passes. Both of these extraction heaters are on the same deck as the ejectors directly below the turbine room floor.

From the last extraction heater the condensate is passed through a 7-in. line to the jet heater, where it becomes injection water, sprayed by means of nozzles to condense whatever auxiliary exhaust steam is being supplied by the steam-driven auxiliaries. Up to the jet heaters, the condensate from each of the two main units is kept separate but just before entering the jet heaters there is a tie valve between the two units.

An 8-in. tail pipe carries the water away from the jet heater to the boiler feed tank located immediately below. raised to 210—212 deg., thus excluding air leaks in the system and preventing the water from absorbing oxygen; the latter would occur if the auxiliary exhaust were carried under a partial vacuum. Possible operating conditions might give exhaust steam from the house turbine or from one or both of the two turbine-driven boiler feed pumps or from both sources together. At the same time extraction steam is present. Because of the maximum temperature of the steam from the lowest bleed point, it was determined to bleed all the steam possible from this point; it is the cheapest steam available for heating feed water. But the quantity of steam bled from the next highest point requires regulation of the quantity of auxiliary exhaust steam available.

Thermostat Automatically Controls Steam Bled From Second Lowest Bleed Point

This regulation is accomplished by putting a sylphon thermostat in each boiler feed tank to operate balanced pilot valves. The valves in turn admit house service water from the essential water system to a diaphragm-

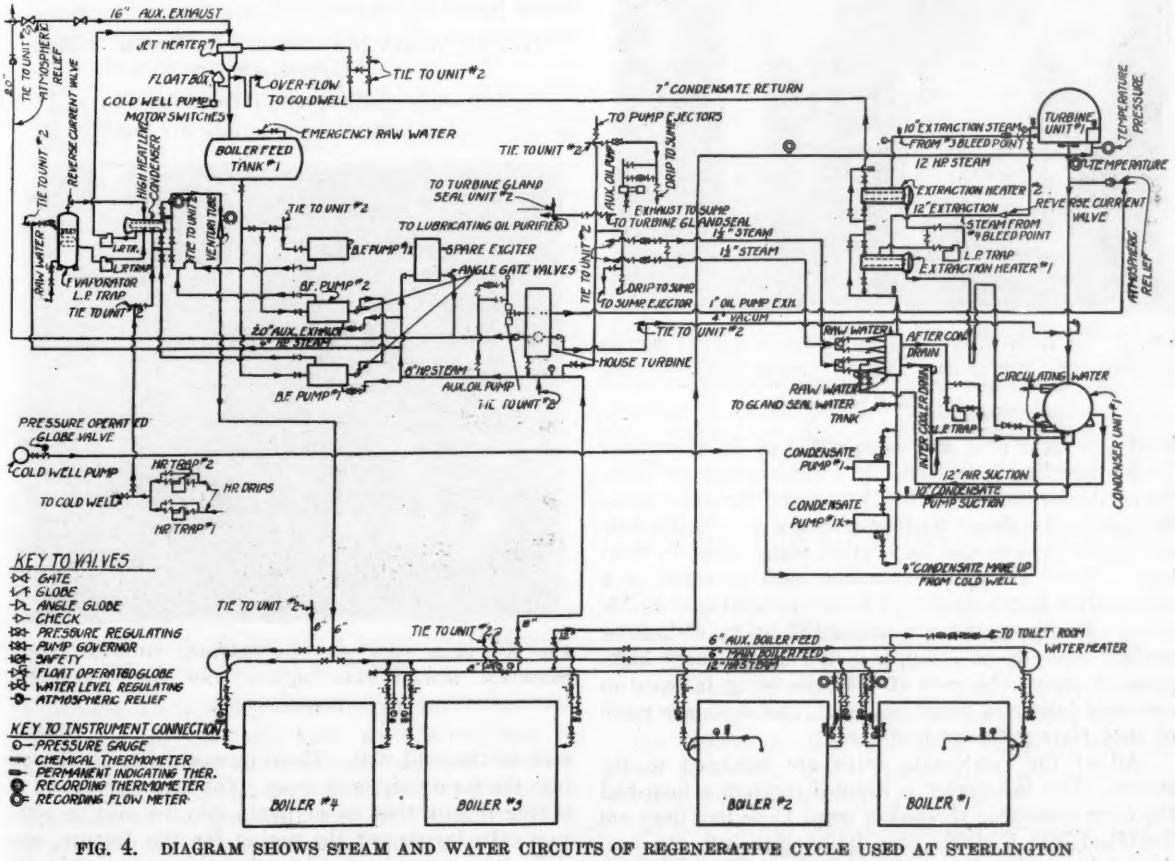


FIG. 4. DIAGRAM SHOWS STEAM AND WATER CIRCUITS OF REGENERATIVE CYCLE USED AT STERLINGTON

The elevation of the water in the system is maintained at a point in the lower body of the jet heater and is subject to some small amount of variation.

In working out the heat-balance scheme, jet heaters presented a limiting factor, namely, the temperature to which they are capable of heating water at atmospheric pressure. This temperature is about 207 deg. F. but, by carrying approximately one pound back pressure on the auxiliary exhaust system, the temperature may be operated pressure reducing valve in the 10-in. steam line to No. 2 extraction heater. Hence, since the thermostat is set for 212 deg., this temperature is maintained in the boiler feed tanks, the amount of extraction steam used depending on that required to secure this temperature of the water when it has been heated by whatever auxiliary exhaust steam is available. In operation this regulation works on the small temperature differential of less than 5 deg. in the boiler feed tanks.

Outlets of the two boiler feed tanks are combined in such a way as to furnish the suctions of the three boiler feed pumps, the same arrangement is used to combine the three pump discharges into two lines to enter the inlets of the two high-heat-level condensers. This secures the maximum flexibility of equipment at this point, any pump being able to take its suction from either unit and discharge into either boiler feed header, of which there are two. Each of the four boilers has two feed connections, one off each feed header, each connection having a feed regulating valve and bypass around the regulator.

Boiler feed water on the discharge side of the pumps enters the high-heat-level condensers at 210—212 deg. and leaves at 250—260 deg. after condensing the vapor from the evaporators. These condensers are of the floating

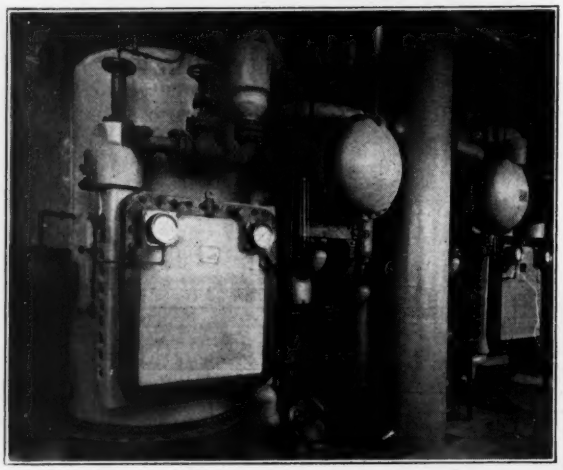


FIG. 5. IN HIGH-HEAT-LEVEL CONDENSERS (LEFT) BOILER FEED-WATER CONDENSES VAPOR FROM EVAPORATORS (RIGHT)

head type, four pass, and contain 333 sq. ft. of surface. Each vapor line is protected by a reverse current valve, the condenser shells by safety valves and the water boxes by vent pop valves. The evaporators are of the weir contraflow type in use for a great many years in England. There are two evaporators each operated as a single effect and incapable of being operated as a double effect. Each evaporator contains 187 sq. ft. of heating surface made up of 7 copper coils and can carry high-pressure steam, the ends of the coils being fastened to cast steel inlet and outlet headers. The shells are made of steel plate with cast-iron bases.

All of the condensate drips are returned to the system. The intercooler is drained through a loop and the after condenser through a trap; these two lines are combined into a single line discharging into the condenser hot well. Extraction heater No. 2 is drained through a trap and the drips flashed in No. 1 extraction heater, which is drained by a loop into the condenser hot well, thus using the usual cascade method. The evaporator coil drains pass through a trap into the high-heat-level condenser where they are flashed. Condensers are also drained by traps of special design, the traps discharging the condensate into the jet heaters overhead.

The low-pressure drip system draining the auxiliary exhaust piping is discharged through a trap into the cold well wherein is stored whatever excess distilled water accumulates. It was thought the low-pressure drips will be sufficient to maintain the temperature of the water in the cold well at approximately 100 deg.

All of the high-pressure steam system is drained through the high-pressure drip system, consisting of two traps. This water is normally discharged into the high-heat-level condensers where it is flashed. Whenever the evaporators are out of service, the high-pressure drip system can be discharged into the cold well where its heat is also available for warming the stored make-up water.

The only waste of exhaust steam in the entire plant is that from the three turbine auxiliary oil pumps, this exhaust being disposed of to the sumps because of its contamination with lubricating oil.

The overflow of the system, or any excess water therein, is discharged from the highest point of the system, the jet heaters, each heater being equipped with a U-seal discharging into the cold well. Any excess pressure on the water boxes of the high-heat-level condensers is also passed to the cold well.

Make-Up Water Is Flashed Into Steam in Main Condensers

To introduce distilled water from the cold well into the system, two vertical sump pumps are installed in the

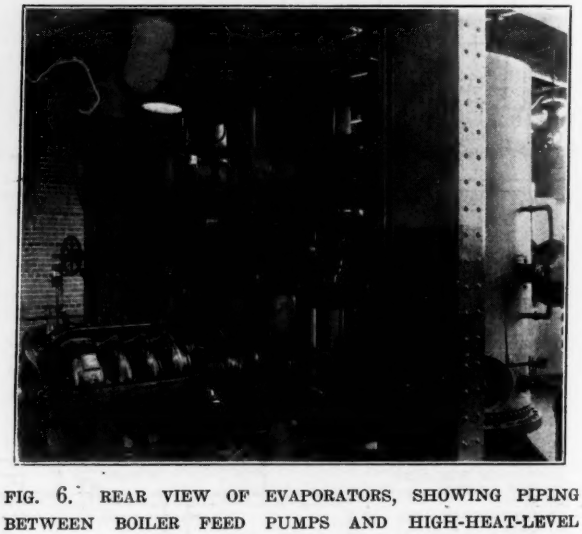


FIG. 6. REAR VIEW OF EVAPORATORS, SHOWING PIPING BETWEEN BOILER FEED PUMPS AND HIGH-HEAT-LEVEL CONDENSERS

roof of the cold well. These pumps discharge directly into the main unit condensers. The arrangement of the piping is such that either pump may be used on either unit. In laying out the piping for this feature, some difficulty was experienced in that the water in the cold well is at atmospheric pressure and the discharge of the pumps would be under whatever vacuum existed in the main unit. Consequently, pressure operated diaphragm valves were placed in the discharge line of each pump, these valves functioning so that, when the pump is in operation and a pressure is built up on its discharge, the water will flow through the make-up line into the condenser where, due to the lower pressure and temperature, it is flashed into steam. This method of operation then permits a certain amount of deaeration of the

make-up water. Instead of introducing relatively cold make-up water into the boiler feed-water system, the temperature of the water introduced into the condenser will be brought up gradually because before it reaches the boiler feed pumps, it will have passed through the extraction and jet heaters. An emergency raw water connection is provided at one point in the system in that each boiler feed tank is connected with the essential house service water system.

In laying out the auxiliary electrical system it was planned so that the main generators would feed the auxiliaries through a house bank of transformers connected to the station auxiliary bus. Furthermore, in case of an emergency the auxiliary bus would also be energized by a house alternator. But to obviate the necessity of maintaining a house alternator in continuous service, it was decided to float such an alternator on the system as a synchronous condenser. Consequently, the 625-kv.a., 80 per cent power factor, turbo-generator used as a house turbine in the Sterlington Station is always electrically connected with the station system through the auxiliary bus. If for any reason the flow of energy to the station is interrupted, a drop in synchronous speed of 5 per cent of the house alternator permits the governor on the steam valve of the house turbine to open immediately and the unit thus becomes a generator supplying current to the essential station auxiliaries. To avoid spinning the turbine rotor in steam, the turbine casing was connected by a vacuum line to both main unit condensers. Although, the vacuum in the house turbine casing is not as high as that in the main unit condensers, it is sufficient to keep the rotor cool. The rotor is of a particularly rugged construction and carries two rows of impulse blades. An atmospheric relief valve is placed on the 20-in. exhaust line from the house turbine and whenever this unit becomes a generator this valve opens and the turbine exhaust is passed directly to the auxiliary exhaust system. At such a time, of course, through the thermostatically controlled valves, steam is automatically cut off the No. 2 extraction heater.

The feed water system is vented at several points. The extraction heaters are vented directly to the main unit condensers. The jet condensers are vented to the atmosphere, as are also the high-heat-level condensers. By properly throttling the globe valves in the vent lines from these heaters, all the air is passed out and practically no steam is permitted to escape.

Complete Data Are Furnished by Instruments

That the operators may know what is occurring in the system, water and steam temperatures are indicated by permanent, industrial type thermometers. A record is also made of the temperature of circulating water in and out, of the temperature corresponding to the vacuum and of the feed water. Suitable double spring pressure gages indicate the condensate pump discharge pressure, the boiler feed pump discharge pressure and the feed water pressure at the boiler inlets.

Quantities of water are recorded at two points. There is in each boiler feed header a venturi tube whose instrument indicates, integrates and records. Steam flow from the boilers is recorded by orifice type meters and the same type of meters are used in the turbine steam leads. Displacement meters are installed on the make-up pump discharges as well as on the evaporator feed lines and continual blow-down lines.

Mention has not yet been made of some of the equipment considered but not installed. Economizers were not warranted because, in a regenerative cycle, there remains little work for them to do. Economizers and air preheaters cannot at this time earn their own carrying charges because of the cheap fuel in use. Provision was made in the design of the boiler room, however, for either of these pieces of equipment to be placed on top of the boilers in the future when the life of the natural gas field shall be exhausted, at which time the boilers are likely to be fired with pulverized fuel. Depending upon the exit temperature of the gases, it is probable that air preheaters will then be found more desirable for economy, since their design will have reached a point at which, because of better heat transfer rates as developed by advances in the art, the terminal differences will be lower.

In the Sterlington layout no new engineering principles were incorporated in the design of the heat-balance equipment. Some of the applications of familiar principles have been used only in the more recent large central stations. The results secured from preliminary commercial service indicate that the calculated economy of the station will shortly be reached and will be comparable with the published operating figures of larger stations, using the regenerative heat cycle and fired with pulverized fuel, in which a kilowatt-hour is delivered to the bus bars for 1.1 to 1.2 lb. of coal. No difficulties other than those incidental to the adjustment of new equipment in service were experienced in starting the Sterlington Station on its useful career. The writer's task was immeasurably lightened by the thorough and wholehearted cooperation of the chief engineer of the station, R. L. Phillips, as well as his operating force; these men all spent many hours to adjust the many complexities of central station equipment to obtain in everyday practical operation the fulfillment of the designer's ideas.

Equipment Installed in Richmond Station

In the article describing the new Richmond station of the Philadelphia Electric Co. which appeared in the May 15 issue, all reference to the equipment installed by the Yarnall-Waring Co. of Philadelphia, was omitted. This company furnished the following equipment:

48 Yarway tandem blow-down valves on the main boiler blow-down line. These valves are built for a working pressure of 420 lb. per sq. in.

36 1-in Yarway blow-down valves for use on the furnace walls and water screens.

3 Yarway-Lea, V-notch meters with a combined capacity of 610,000 lb. per hr. Two of these are for measuring boiler blow-down while the third measures the sludge from the evaporators.

1 Yarway-Lea, V-notch meter of one million pounds per hr. capacity. This meter is used as a test meter for checking and calibrating all other meters and boiler instruments in the station. It is guaranteed accurate within one-half of one per cent at all rates of flow.

Good Design Increases Life of Furnace

CHANGES WHICH WERE MADE IN THE SETTING OF AN OIL-FIRED BOILER AND THE BENEFITS RESULTING. BY FRANK A. ROTHWELL

SO SIMPLE is the arrangement of a furnace for burning oil fuel that few engineers give it the consideration that is its due. Fuel oil atomizers can be applied to any furnace with a considerable degree of success from efficiency and capacity standpoints but the same is not true in regard to the longevity of the furnace lining. In the oil-fired furnace, temperatures are necessarily high, if the fuel is burned efficiently, with low excess air.

LIFE OF REFRACTORIES DEMANDS ATTENTION

Due to these high temperatures, the matter of refractories requires most careful consideration. With a first-grade brick, the refractory service is prolonged to

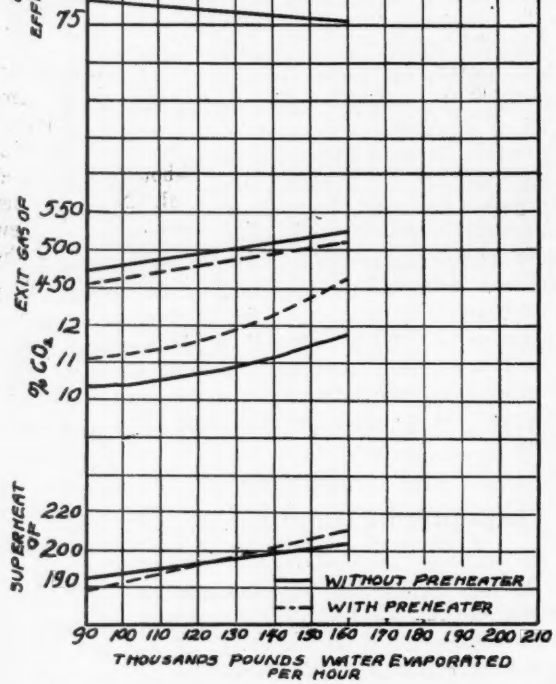


FIG. 1. COMPARATIVE PERFORMANCE OF A BOILER WITH AND WITHOUT PREHEATED AIR

some degree over that for second-grade brick under the same conditions but the object is to prolong the life of any brick as much as possible. Recently, undue pressure seems to be brought to bear on manufacturers of refractories to furnish a general panacea for all furnace failures. Some of the trouble may be due to manufacturers not keeping pace with the advancement of furnace development. Each season appears to usher in considerable increase in the minimum demand that must be met by furnace linings but the writer believes that the power industry is justified in throwing on the refractory man at least a considerable part of the cause of our troubles.

In January, 1925, Thomas S. Curtis, Director of Research for the Vitrifrax Co., delivered a most interesting address before the Los Angeles section of the A. S. M. E. on Refractories for Oil-Burning Boilers. In the course of the paper, he said, "The best clay brick that can be made, without regard to cost, is subject to drastic changes under intense reduction." If, then, we use the best clay obtainable, we still continue to experience furnace failures at excessive temperatures and dead load pressures.

FURNACE DESIGN MAY ABUSE OR CONSERVE THE LINING

Specific data as to just what is desired in refractories for a given service are hard to procure. It is easy to say that the perfect fire brick is one whose critical point of plasticity lies well above the working temperature of the furnaces but such a statement takes no account of the severity of the service required. With more regard to the limiting possibilities of refractories, we can change the statement to read: design the furnace so that the working temperature of the walls will be well below the critical point of plasticity of the fire brick. Such a rule is entirely practicable to follow as will be shown.

It is quite safe to say that but a small percentage of the buyers in the field consider fusion point, hardness, expansion, compression, size of nodules and ratio of nodules. It is the usual practice to purchase a No. 1 fire brick, which is trusted to have all the admirable qualities needed for lengthy service. Even though a fire brick of the best quality is used, it can be quickly deteriorated by improper furnace design. Combustion conditions and furnace design are advancing by great strides but there is a lack of general appreciation that refractories will fail, if subjected to drastic conditions. This is more true when speaking of oil-fired furnaces than of others, partly because the conditions there are more drastic than in furnaces for other fuels.

In his paper, Mr. Curtis goes on to say: "If air cooling is desired, we favor it highly, since, if the preheated air is used for combustion, no loss in efficiency is suffered and the brickwork is helped out tremendously." Air-cooled walls have had a certain amount of attention for some time but to what extent such construction has affected the length of refractory service is not known, up to the present time, due to insufficiency of data.

AIR COOLING OF WALLS ADDS TO LIFE AND EFFICIENCY

It stands to reason that, if the heat conducted from the furnace wall is used to heat the air for combustion, the affinity of the fuel oil for the air is increased as well as prolonging the life of the refractory due to the air cooling. Therefore, by such construction we may design a furnace whose wall temperatures are well below the critical point of plasticity of the fire brick and, at the same time, aid the fuel economy of the plant.

In tests by Ray and Kreisinger reported in Bulletin No. 8, Bureau of Mines, it was conclusively proved that a solid wall was a better heat insulator than a wall of the same total thickness having an air space in the

middle. Construction with such a dead air space is not an air-cooled wall and cannot be so considered. Hollow walls through which currents of air are passing have a distinct advantage over any solid wall construction as a means of lessening radiation to the outside atmosphere.

Gains from Ventilated Wall Construction

Although the primary reason for ventilated wall construction is to reduce refractory failures, a certain percentage is gained in each of the features which influence boiler performance. In Fig. 1 are shown some curves which represent the performance of a boiler with and without this feature of preheated air being used for combustion. These curves were presented by C. W. E. Clark in the Transactions of the A. S. M. E. for 1923, the air in this case being heated by the exit gases and, of course, having no effect on refractory service. But they show that by reclaiming heat from the furnace walls and at the same time cooling them, the setting life is increased and boiler performance will be bettered.

During the past 2 yr., a specific installation of air-cooled walls has proved conclusively their superiority over several other types that were tried out.

Steps and Results in Improving an Oil-Fired Furnace

In 1921, the company with which the writer is connected was experiencing considerable trouble due to refractory failure. This was so severe as to cause much anxiety over generating enough steam for process work. The boiler capacity was limited and experimenting could only be done in the time that the boilers were taken off the line and rushed back onto the line. The cleaning time was made as short as possible. With a later addition to the plant, sufficient capacity was gained to allow some degree of furnace development to relieve the trouble.

Original units were 600 b.hp. and were equipped with the rear-shot type of furnace as shown in Fig. 2. The capacity that was demanded was far above that at which the furnaces could operate satisfactorily, as it is generally known that a furnace of this type has a limited overload ability. In trying to force such a furnace, a deficiency of air is encountered so that at certain rates of combustion, excessive furnace temperatures result. Above this rate, at which the deficiency of air is encountered, the consequent impinging of the flame upon the furnace walls causes them to slag and fill the air ports in the floor of the furnace. At times this slagging was so severe that the boiler had to be taken off the line to remove and clean the atomizers which had become fast due to the filling of the atomizer ports with slag. The side walls slagged so badly

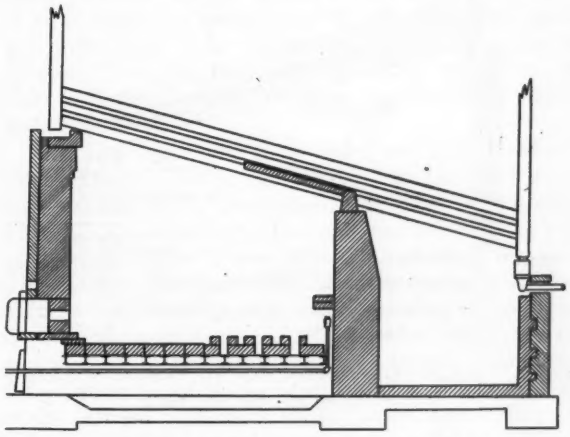


FIG. 3. REVISED AIR PORTS TO PREVENT FILLING UP WITH SLAG

that within three weeks the air supply fell below that needed for anything like satisfactory operation.

While the air ports were clear, it was possible to carry the load but without much leeway for extra demand. The main need seemed to be to keep the air ports from filling up in order that longer operating periods could be obtained before taking the boiler off the line. In Fig. 3 is shown the method employed to prevent the ports from filling so soon.

Instead of holes in the floor, slots were built reaching clear across the furnace, these slots being 4½ by 36 in. and run in sets of three. Around the edges of the slots was placed a tier of brick to form a barrier so that the slag would less quickly run into the ports or slots. Also an arch was built over the atomizer to deflect the air horizontally and assist in keeping the opening around the atomizer in a cooler state and eliminate, to some extent, the tendency of the atomizer to coke up

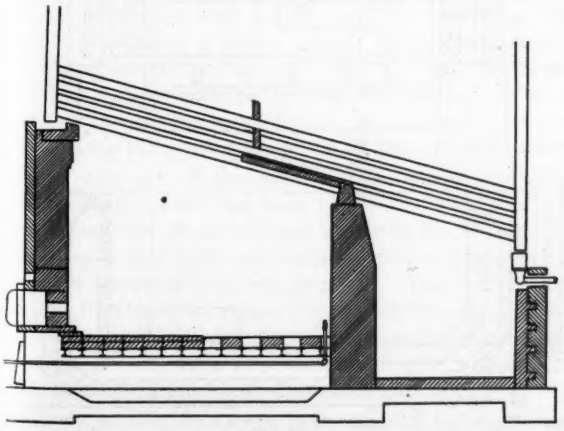


FIG. 2. ORIGINAL FURNACE INSTALLED UNDER 600-B.HP. UNITS

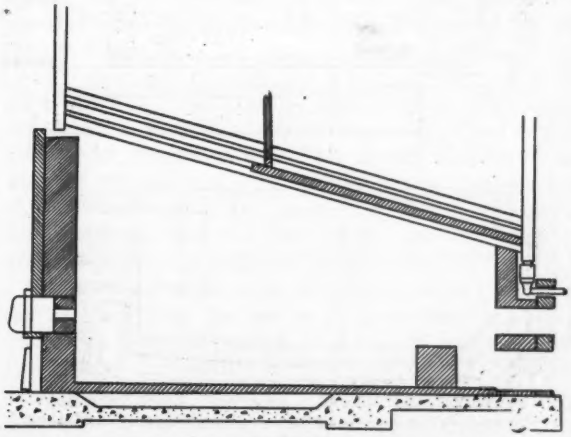


FIG. 4. FURNACE REMODELED TO INCREASE COMBUSTION SPACE AND ELIMINATE AIR PORTS

as well as preventing the slag from completely filling the atomizer port or, at any rate, to delay the process. This arrangement did keep the atomizer opening from filling up, hence the atomizer could be taken out and cleaned; also it prolonged the period of service before cleaning about 12 days but there was still present excessive slagging of the side walls and final filling up

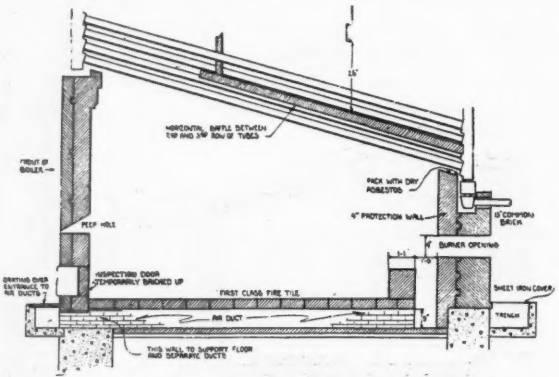


FIG. 5. FALSE FLOOR INSTALLED TO REMOVE EXCESSIVE HEAT FROM CONCRETE FLOOR

of the floor slots. The best this setting could do was six to seven weeks' operation without repairs to side walls or floors and air ports had to be dug out after every run.

As data taken made it quite evident that the furnaces were inadequate for the service demanded, it was decided that an increase in furnace volume might tend to eliminate the impingement of the flame on the walls and by a different arrangement for air supply the air ports in the floor could be eliminated. Figure 4 shows a complete revision of the original furnace, the dividing wall of the combustion chamber being removed, the horizontal baffle continued to the rear header and the furnace floor dropped to the boiler room floor level. With this arrangement, the combustion space was doubled and the air ports eliminated by taking the air for combustion from the rear of the setting. The change required all atomizer equipment to be placed at the rear of the boiler.

This construction allowed of operation for an indefinite period so far as combustion conditions were concerned but the high temperature on the solid floor caused the concrete to crack and crumble. This deterioration was only about 25 per cent of that with the original setting and the boiler was on the line some 300 per cent longer but combustion at high rates was not as satisfactory as it should have been due to cold air being used for combustion.

Air-Cooling the Floor Was Tried

Again the setting was revised and a false floor installed as shown in Fig. 5. This was done primarily to reduce the excessive temperatures of the concrete floor so as to eliminate cracking and crumbling. All of the air for combustion was taken through the ducts under the false floor and operation could be continued indefinitely without floor repairs while the preheating of the air helped considerably the process of combustion. As far as combustion conditions were concerned there was little left to be desired but there was still the trouble with ultimate failure of the side walls. It was reasoned that, if the air cooling eliminated trouble with the floor, why not cool the side walls and eliminate failure there? And the result of this reasoning was put into reality by constructing the setting shown in Fig. 6.

For two years, eight of these settings have been in operation and it is thought that at the present time

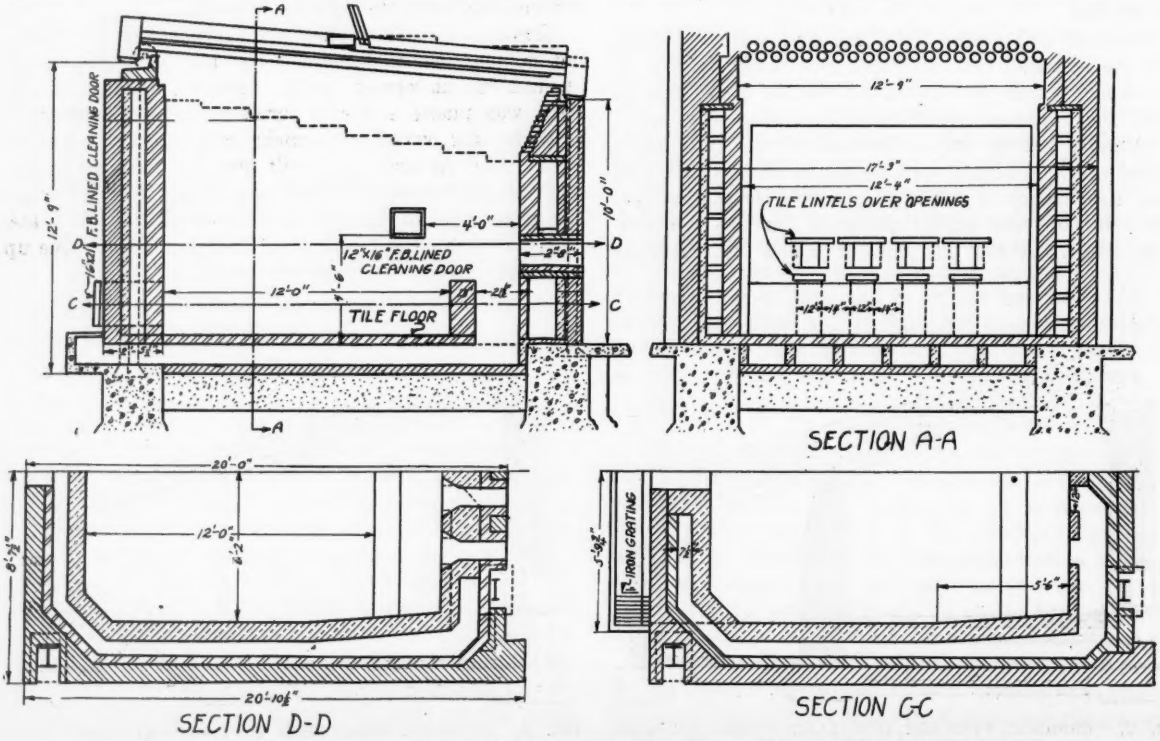


FIG. 6. THIS SETTING COMPLETED 15,928 OPERATING HOURS WITHOUT BRICKWORK REPAIRS

sufficient data are in hand to present a definite report of their practicability.

These settings are under 600-hp. units. The main source of air supply is from under the furnace floor, the air coming in through six ducts, each 1 ft. 9½ in. by 10 in. Air enters the grating at the front of the boiler and flows to the rear where it deflects upward and meets the tip of the atomizer. The air duct around the walls is 7½ in. wide and separates the two walls which are tied together with 16-in. by 4½-in. by 2½-in. fire brick, placed 9 in. apart and laid every fifth course. The inside wall of the setting is 9 in. thick of No. 1 fire brick. The outside wall is 13½ in. thick, made up of 4½ in. of fire brick on the inside and 9 in. of common brick on the outside.

In the construction of these furnaces, 18,000 No. 1 fire brick were used and 22,000 common red brick. When laying up the inner wall, the fire brick were dipped in a thin batter of No. 1 fire clay and as the brick were placed, they were tamped until all the excess of clay was forced out of the joint. This left a very thin coating of clay between the bricks which served more as a mucilage than a mortar joint, making a wall face of practically solid brick, which eliminated, to a great extent, the tendency to erosion and corner abrasion. The outer wall of common brick was laid with the usual ⅜-in. mortar joint.

That these settings approach nearly to the ideal for oil burning is shown by the following data, taken from a 24-hr. test.

Per cent rating developed, 212. Stack temperature, deg. F., 497. Furnace draft, in. of water, 0.06. Breeching draft, in. of water, 0.18. CO_2, per cent, 14.2. O per cent, 3.0. CO per cent, 0.0. Per cent excess air, 10.0.

Units operate at a required load of 185 to 250 per cent of rating and are on the line from 30 to 35 days at a time. When operating at around 195 per cent of rating, the wall temperatures are about 2000 deg. F. and the flame temperatures between 2500 and 2600 deg. F.

Approximately 15 to 20 per cent of the air for combustion enters the combustion chamber from the side wall passages and it is heated from 90 deg. to 400 deg. before it enters the combustion chamber. The outside walls are 45 to 65 deg. cooler than they were with the former construction. Any rate of combustion is obtained and maintained under excellent conditions, the higher rates being possible without the smoke nuisance usually attendant when using cold air for combustion and high velocity atomizers. The most marked improvement is in the increased length of refractory service, which alone has proved the worth of the air-cooled walls.

For any one of the settings, the longest operating time without repairs has been 15,928 hr.—one year, ten months and ten days—without repair to brickwork. At that time, a side wall was repaired, due to burning out from an improperly-placed atomizer. The shortest operating time without repair for any of the settings was 10,894 hr., a year, six months and twenty-three days. Such length of refractory service is quite out of line with that of the usual oil-fired boiler setting.

It should also be known that seven of the eight furnaces were laid with a fire brick costing $12 a thousand less than that for the eighth, which was a widely-known brand of excellent grade. The lower-grade brick has stood up well as compared with the more expensive material and is giving equally good service, the longest run mentioned being with this cheaper brick.

Cubical displacement of the furnace is 2160 cu. ft., which is a ratio of 3.30 cu. ft. per rated boiler horsepower. This easily allows for operating at 300 per cent of rating without forcing the furnaces to any appreciable degree. In the design of oil-burning furnaces it is advisable to allow 1 cu. ft. of combustion space per anticipated boiler horsepower that will have to be developed, without regard to the rating of the boiler. This ratio can be used for either mechanical or steam atomization.

At the present time, 2 yr. and 1 mo. since these settings were first put in operation, all of the front walls have been repaired, due to the bulging out of the wall. This was a mechanical defect and was remedied in the repairing. The wall was built too tight and the continued expansion caused the bulging but none of the walls were sufficiently eroded to cause need for repairs. Of the sixteen side walls, only seven have been repaired and the outside walls have given no trouble except for the pointing up of cracks caused by the first expansion of the furnace. An order for brickwork repairs is rare indeed. For the first 18 mo. the battery of settings operated without a brick layer being called on the job and we began to wonder if it would be like the "Wonderful One Hoss Shay" and go to pieces all at once.

From the data presented, it would seem quite feasible to design a setting whose wall temperatures are well below the critical point of plasticity of the fire brick and, by so doing, a poorer grade of refractory can be used with the same results as for the more expensive. With such consideration given to the refractories, there seems no reason why brickwork failures cannot be reduced to a considerable degree and the refractory man given a little peace of mind. From two years of observation, I am in accord with Mr. Curtis that the brickwork is helped tremendously.

Man Power Replaced by Machinery

MECHANICAL operations have greatly increased production over that possible by hand labor, every such replacement involving the use of power. The extent to which this has been done was cited by Julius H. Barnes, president of the Chamber of Commerce of the United States in a recent address before the American Economics Association as follows:

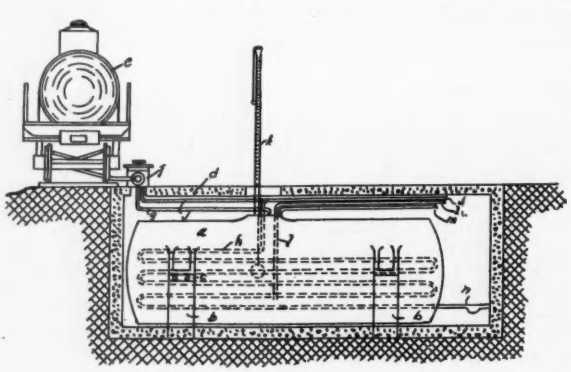
"In steel and iron, two men with unloaders can do the work of 20 men unloading by hand; furnace charging by skip hoist, carry and automatic weigher takes two men in place of 14; seven men with a pig casting machine do the work of 60; one man with an open-hearth charging machine does the work of 40; for pouring, 12 men with traveling cranes can take the place of 37; two men with an electro-magnet and crane can do the work of 128.

"In other industries, such as clothing, shoes, glass, mining and wrapping, the use of power-operated machinery increases a worker's product from 3 to 25 and sometimes to 40 times that possible with hand labor. The tendency extends into office work, agriculture and merchandising. And labor is not, thereby, released to unemployment, but new industries are established in the manufacture of machinery and there is enlargement of old industries."

Fuel Supply System for the Diesel Engine

CARE NEEDED IN ESTIMATING SIZE OF STORAGE TANK REQUIRED AS WELL AS IN ITS INSTALLATION AND PIPING. BY C. C. HERMANN

TO OBTAIN price concessions we must purchase fuel oil for Diesels in quantities. To take advantage of market conditions we must purchase when the market is favorable. With even a moderate consumption the least reserve supply should not be less than a tank car. A tank car means nine to ten thousand gallons. Take for example an ice plant. The Diesel is probably used more generally in ice plants than any other kind of power. The fuel consumption per ton of ice varies from four to six gallons. A 50-t. plant would therefore use approximately 250 gal. of oil per day. Fuel consumption of a Diesel engine operating a sand dredge runs about 0.5 lb. of fuel per horsepower-hour for a 225-hp. engine running 10 hr. per day. This makes a fuel consumption of approximately 160 gal. per day. A tank of oil would be about 60 days' supply in the latter case and about



UNLOADING TANK CARS BY GRAVITY IS A DISTINCT ADVANTAGE OF UNDERGROUND OIL STORAGE

six weeks in the former case. Obviously with even a small engine the storage should not be less than a tank car at a time.

Capacity of the oil storage, besides depending on the daily consumption, must be in harmony with the availability of supply, distance from the supply, promptness of shipment and railroad facilities.

Storage should be such as will permit unloading from the tank car by gravity although a number of plants do the unloading by pump. Since the underwriters requirements are such as to require that the storage tank shall be outside and below the floor level of the engine room the underground tank for storage suggests itself as the most economical solution of the problem. The tank may then be located along side of the unloading track and below grade level. Two courses are open and the selection depends upon the surrounding conditions as well as the permissible initial expense allowed in the storage installation. The open tank room is preferred to the covered or buried tank. Having the tank in an underground room permits inspection of the tank for leaks and provides accessibility in case of repairs. Where the tank is buried in the ground a leak may go unnoticed for some time particularly if there are any drains in the vicinity.

When a tank is buried it should be protected from above the ground. A tank may easily be damaged by placing considerable weight on its outside surface, as may result from simply burying the tank and not protecting the plot above. If the space is to be used for storage the tank should be protected by a reinforced concrete slab or floor work of ample strength placing the entire load on side walls and in no wise on the tank. The tank must be left free to expand and contract with changes in temperature or rupture will result. Obviously if the tank is carrying a load superimposed upon it consisting of considerable earth and piles of stock thereon, it cannot contract and expand freely. The earth packs down around the tank and the continual working of the mass serves to wedge the tank firmer and firmer. The action is like tamping railroad ties with a shovel. The earth is packed very firm.

The tank should be supported on rollers on one end, preferably the end opposite from where the pipe connections are made. The expansion will then take place away from the pipes, the friction between the tank and the support under this end serving to hold it against movement. The piping should not be installed, however, with absolute reliance on this restriction of movement of one end of the tank. The piping should be installed with the swing joint in the foreground so that any movement of the tank will either screw or unscrew the pipe connection the small amount encountered. While it is true that this keeps the screw joints more or less loose I have the first joint to find leaking from this cause. The movement is extremely slight if any when the tank is installed as indicated above.

With regard to the unloading station, some means should be at hand for straining the oil. I have seen articles from a rivet head to a monkey wrench come out of tank cars and it is just possible that the piping from the car to the tank will not pass some of this junk, resulting in the clogging up of the pipe and its consequent removal in order to effect a cleaning of the pipe. The strainer need not be very fine, preferably about ¼ in. mesh.

In the sketch is shown a typical fuel oil storage installation consisting of a 10,000-gal. tank *a* carried on the supports *b* with the rollers *c* between the bracket and the rear support. The tank is protected from above by the reinforced concrete slab *d* carried on side and end walls. The tank car *e* is spotted so that its under connection can be made with the unloading strainer box *f* on the end. The box contains a screen through which all oil must pass before entering the pipe *g* leading to the tank.

The tank is supplied with a steam coil *h* of sufficient heating surface to raise the temperature of the oil up to 125 deg. for the purpose of facilitating its handling by the transfer pumps. A steam line *j* is also carried out to the track to be used in heating the oil in the tank car when necessary. Tank cars are equipped with steam coils for this purpose.

The tank is also provided with a gage *k* for indicating the amount of oil in the tank. These gages may be calibrated in gallons, which permits a direct reading.

The suction pipe for the transfer pump is shown at *l* and the overflow pipe at *m*. The object of the overflow pipe is to allow the excess oil over and above that to produce a given pressure in the distribution line to flow back into the tank. The water end of the steam coil *h* is provided with a trap *n* and the condensation returned to the boiler room.

In the tank installation shown in the figure, all piping except the return of the coil enters the top of the tank. This eliminates the possibility of a pipe breaking and the oil emptying into the pit.

Selection of a transfer pump suitable for Diesel work can be made from among a number of pumps of both the rotary and plunger type which are on the market. Suffice to say here that it is preferable to have the fuel pump combined with the cooling water pump in such a manner that should the cooling water supply fail the fuel pump will also stop and thereby avoid damage to the engine. The Diesel uses from 10 to 30 gal. of cooling water per brake horsepower-hour depending upon the allowable increase in temperature of the water which may be as high as 130 deg. outlet temperature where the water does not contain encrusting solids which would be precipitated under this temperature.

The transfer pump merely removes the oil from the storage tank to the auxiliary fuel tank on the engine, whence it flows by gravity to the injection pump. The auxiliary tank is also provided with heating means principally by reason of its proximity to the engine cylinders and the circulation of hot water around it from the water jacket of the engine.

Spare Parts in Oil Engine Operation

ENGINEER AND GEOGRAPHICAL LOCATION SHOULD BE CONSIDERED. BY A. B. NEWELL*

ALTHOUGH it is impossible to cover this subject in its entirety, it is nevertheless sufficiently important to warrant careful consideration. Those who have been over-anxious to avoid heavy expense and as a result cut down on the spare list, have in the long run paid dearly and taught us many valuable lessons.

Oil engines of today do not require as many spares as did those of 10 yr. ago, and another 10 yr. will see a further reduction. We have better engines, more capable engineers, higher grades of lubricants and fuel, innumerable methods and instruments for checking up on performance while manufacturers are better prepared to make prompt shipments. Despite all of this there are certain inherent weaknesses in the engine room staff and vulnerable spots in the engines which must be taken into account when considering spare equipment.

The engineer is an uncertain quantity. The engine is more dependable. If we attempt to insure against human fallacies and play 100 per cent safe, a spare engine would be almost the only complete list of spares. As for the engine, its weaknesses are so well known that an almost complete prediction of what will be required, and when, can be made.

Items which will be mentioned later cannot be taken as representing more than a list for one plant and are only suggestions made with a view to emphasizing the need of such parts.

Throughout the country we have many more small oil engine units than large ones. Most of these are simple and sturdy little engines yet they require an extra fuel valve or two, some spare fuel pump valves, springs and plungers, a complete set of all other springs, some scavenging pump valves, an extra starting valve and cage and a set of piston rings. If it were sent abroad other items such as a piston, cylinder head, bearing shells, crank boxes, top and bearings, gudgeon pins and perhaps some other parts would be needed. If it were a four-cycle engine, exhaust and air inlet valves would have to be added, as would air compressor parts if it employed the air atomization method of fuel injection.

Certain frail parts such as fuel nozzles and valves last but a limited time and their periodical replacement is known to be a routine maintenance expense. Piston rings may also be considered perishable in service.

FEW PARTS FREE FROM WEAR

Then there is the question of pistons, cylinder heads and cylinder liners. The fuel pump is made up of many small working parts which must be so exact in their functioning that no wear of any consequence may be countenanced, yet these parts do wear. Air compressor valves, valve seats and cages require periodical attention. Air compressor piston rings wear out, sometimes quickly and unexpectedly, particularly when foreign substances and active gases find their way into the inlet breather.

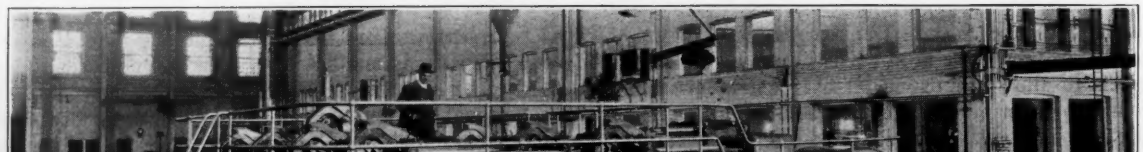
Certain parts are dependent more than others upon how the operating engineer takes care of things. He is responsible for the condition of combustion, unless his employer insists on carrying an overload on the engine or some other similarly detrimental misinterpretation of economy. To charge all mistakes in operation to indifference is not fair, for we all make mistakes at times. Therefore, in ordering such parts as pistons, cylinder liners and heads, crank and main bearings, we are only insuring against time losses which will be very expensive and may strike any plant at any time.

*American Brown Boveri Electric Corp., Camden, N. J. Abstract of paper presented before Oil and Gas Power National Conference, April 19-24, 1926.

Heating with Diesel Engine Cooling Water

AN INTERESTING installation has recently been carried out in connection with the electric power station at Schwerin, Mecklenburg, Germany—that of utilizing the cylinder cooling water and exhaust gases of the Diesel engines which run the generators for heating a bank and some official buildings located at a distance of ¾ mi. The water which leaves the cylinder jackets of the engines at a temperature of about 176 deg. F. is passed through the exhaust box, where it is heated up to 188 deg. F. and then circulated by a pump through underground pipes.

Although the owners of the premises are effecting a saving of 20 per cent in the cost of heating their buildings as compared with direct heating and firing, the installation is proving remunerative to the municipal electric plant, which is stated to be getting a return of at least 10 per cent per annum.



Record Breaking Uniflow Engine in Steel Mill

LARGEST UNIFLOW IN AMERICA, INCORPORATING MANY UNUSUAL FEATURES OF DESIGN AND CONSTRUCTION, IS PIONEER UNIT FOR REVERSING BLOOMING MILL SERVICE

WHILE TURBINE manufacturers have been busying themselves with units of record-breaking size, engine builders have not been idle. Two 36-in. by 60-in. 4-cylinder uniflow engines built by the Nordberg Mfg. Co. for the Steubenville Plant of the Wheeling Steel Corp. meet the exacting demands of the steel industry and earn the title of the "Largest Uniflow Engines in the World."

One of these engines, built without a flywheel to drive a 35 in. 2-high reversing blooming mill, develops momentarily a maximum of 30,000 i.hp. at 150 r.p.m., while the second, driving a continuous bar mill, has a maximum continuous rating of 14,000 i.hp. at 75 r.p.m.

This is the first application of a uniflow engine to blooming mill drive; some idea of the severity of the service can be gained by knowing that the engine from running at full load stops, reverses, and picks up full load in the opposite direction in 3 sec., 20 complete reversals a minute. Under these conditions the power output of the engine is a variable quantity, the rating of 30,000 i.hp. being based upon a m.e.p. of 175 lb. per sq. in. at 150 r.p.m. and maximum cutoff. Even the continuous mill engine has a load varying from practically nothing to a maximum steam demand of 118,000 lb. an hour over a cycle of 112 sec. Although the flywheel smooths out the power variation somewhat the wide variation of steam flow called for special condenser design to take care of the pulsations.

In steel mill practice ingots are rolled into blooms of a suitable size by the blooming mill, then fed to the continuous mill for rolling into sheet bar or roll slabs of various sizes for use in the jobbing and plate mills. Older installations used compound reversing engines for blooming mill service while the modern tendency is to favor motor drive, due principally to the favorable power economy shown over the old type steam engine.

Steam economies of the uniflow engine combined with its flat steam consumption curve over a wide range of load compare favorably with motor drive from the standpoint of economy, if installed in a modern plant with proper steam piping, while the saving in first cost is considerable. The advantage of the uniflow over the usual compound reversing engine for this service is brought out by a direct comparison of indicator cards. But 66.6 per cent of the available m.e.p. at 150 lb. steam pressure is realized by the compound engine while under the same conditions a uniflow with fewer losses realizes 77.5 per cent which may be increased to 79.4 per cent by using steam at 240 lb. pressure.

CRANKS ARE ARRANGED TO GIVE POWER IMPULSE EVERY 45 DEGREES

Maximum torque at whatever position the engine may stop is a fundamental requirement for this drive and a 4-cylinder engine with the cranks arranged to give a power impulse every 45 deg. was selected only after the most thorough investigation of 2, 3, 4 and 5-crank engine performance. The 22-in. diameter shaft is of the built up type with webs and pins forged from open hearth steel, reciprocating and rotative forces and movements being balanced by counterweights on the two outer cranks.

With the exception of a few details the two engines are identical and the full set of spares kept on hand can be used on either machine. Foundations are 22 ft. deep, each containing slightly over 1400 cu. yd. of concrete, to which bedplates are secured by fifty 3½-in. and twenty 2½-in. foundation bolts and 2 in. of grout. The bedplate of the continuous mill engine was cast first and proved to be so unwieldy that the second one was cast in three pieces, the additional ribbing and joints necessary increasing the weight about 40 t. as shown in the table giving principal dimensions and weights. These three pieces are shrunk together with links and tie rods to give the required rigidity.

Five two-piece main bearings support the crankshaft,

the shells of cast steel being rough machines and tinned before babbitting. Four of the bearings are 22 by 28 in. the fifth, at the coupling end of the shaft, being 23 by 28 and arranged so as to take the thrust, bearing on one side against the crank web and on the other against a brass thrust collar. In addition to these five, the continuous mill engine has a 23 by 36 in. outboard bearing to support the flywheel which is made in four pieces held together with shrink links placed in the rim and rings shrunk on the hub. Bottom shells of all bearings can be turned out without removing the shaft.

Reciprocating parts are made as light as possible consistent with strength and safety, the piston rod and connecting rod being hollow, the pistons of cast steel made in two parts with no filling piece between, while the cross-heads are of exceptionally light and sturdy forged construction. Details of these are brought out in the longitudinal cross-section of the engine, Fig. 1.

Two 9 by 8¾-in. wrist pins are used for each cylinder as part of the forged crosshead body. Adjustable crosshead shoes operate in cast-iron bored guides, the bearing surface being 20 by 33 in. Connecting rods are of the forked hollow marine type made of forged steel.

Piston Rod Deflection Compensated for by Proper Machining

Piston rods are also hollow, keyed into the crosshead, extending through the cylinder and supported by 18 by 21-in. tail guides. Pistons are therefore of the full floating type and in order to compensate for the deflection of the shaft between supports the rod is machined with a camber upward so that in service the deflection will bring it absolutely horizontal. In this case the unsupported span is 17 ft., the calculated deflection amounting to $\frac{1}{16}$ in.

Three rings fastened by steam-tight keepers are used on each piston, the pistons in turn fitting snugly against shoulders ground on the rods and then secured by lock nuts. Only ⅛ in. clearance is allowed between pistons and cylinder heads. Cylinder castings are as simple as possible, with no footing of their own, being supported between the main frame and tail rod guide. Crank end cylinder heads are removable through the bore of the cylinder.

Valves are assembled in cages as a complete unit, including the valve seat, the steam chests being bolted to the cylinder so that in case of trouble the entire valve chest is replaced. All cylinders are provided with spring

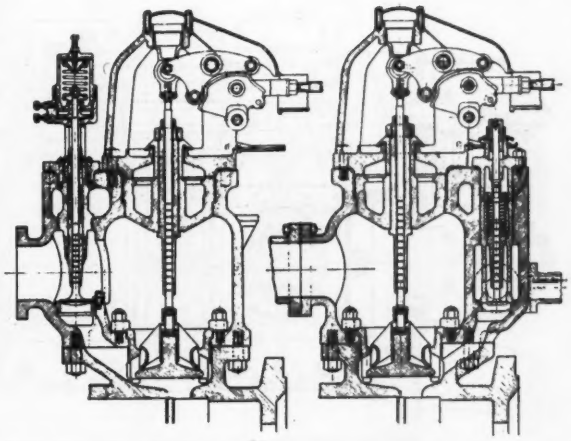


FIG. 2. MAIN STEAM VALVE SHOWING ARRANGEMENT OF OVER COMPRESSION VALVE (LEFT) AND AUXILIARY EXHAUST VALVE (RIGHT)

loaded over compression, or safety, valves as shown on the left in Fig. 2. They open to bypass steam to the steam chest when compression in the cylinder exceeds the pressure in the steam chest itself.

In addition, the reversing engine cylinders are equipped with auxiliary exhaust valves as shown on the right of Fig. 2. This engine is controlled from the operator's pulpit by a single lever varying the cutoff. As this lever is swung past the normal cutoff for either direction of rotation, the cam operating the steam valve receives increased motion and automatically opens the auxiliary valve decreasing compression by bypassing the steam to the exhaust passage. The auxiliary exhaust valves are not normally used, being a safety measure in case the engine should stall or an exceptionally quick reversal be necessary.

These two valves of chrome nickel steel working on monel metal seats are placed side by side, at an angle of about 45 deg. from the main valve stem. Spare valve chests are furnished with both over compression and auxiliary exhaust valves, the latter being blocked off when used on the continuous engine.

No Packing Used on Valve Stems

Main steam valves are double beat balanced poppet valves, both valves and seats being made from a special mixture of cast iron and ground steam tight. They are

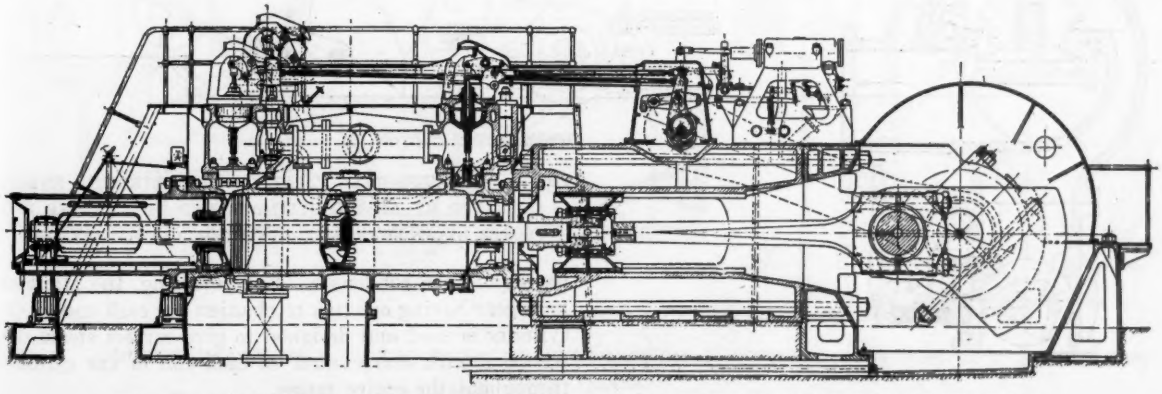


FIG. 1. LONGITUDINAL SECTION OF REVERSING ENGINE BRINGING OUT DETAILS OF DESIGN

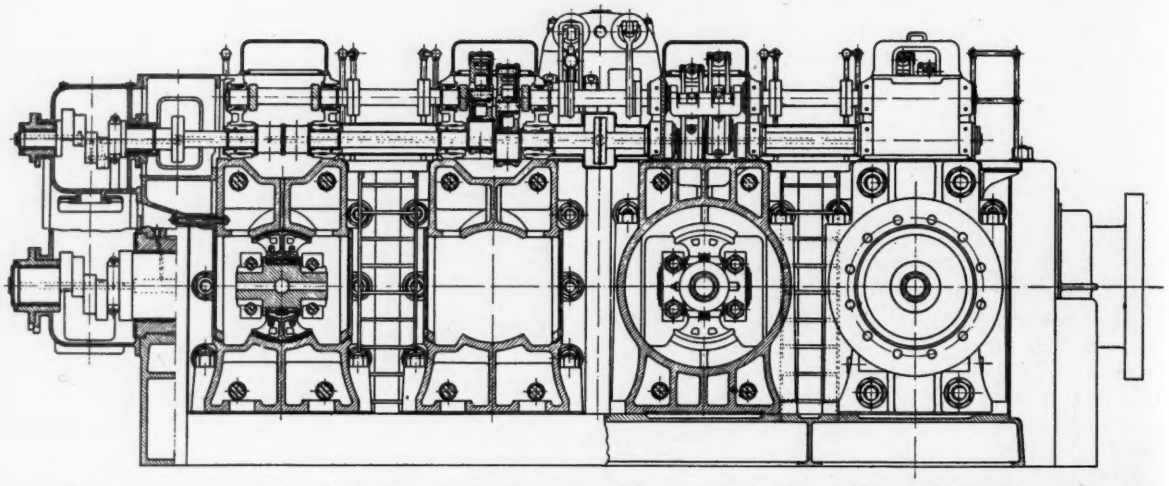


FIG. 3. TRANSVERSE SECTION OF ENGINE THROUGH LAYSHAFT SHOWING FIVE-THROW ECCENTRIC DRIVE AND GENERAL ARRANGEMENT

positively operated by oscillating cams driven by separate eccentric rods from the layshaft. Valve stems are flexibly connected to the valves and are ground and lapped in, the series of grooves filling with oil and water to make a steam tight joint without packing.

Running crosswise above the engine, the layshaft with eccentrics forged integral, is driven by means of five eccentric rods and identical five-throw eccentrics on the crankshaft and end of the layshaft as shown in Fig. 3. This arrangement not only provides a safeguard against breakage but assures movement of the valves irrespective of the crank position.

Every precaution for safety is taken, the throttle valve, shown in Fig. 4, as well as the steam valves being closed when the operating lever is in neutral position, while it opens and closes each time the engine is reversed. At 150 r.p.m. the overspeed governor rings a warning bell placed in the pulpit and at 160 r.p.m. closes the throttle valve. The operator can again open the throttle valve from the pulpit by means of a lever. At 170 r.p.m. a Fall safety stop located under the throttle comes into action, tripped from a contact at the layshaft, and cuts off the flow of steam to the engine. Although this stop may also be tripped by push-button stations located in the engine room and pulpit it must be reset by the engineer before resuming operation.

Automatic cylinder drain valves are provided for each end of every cylinder. These valves, shown in Fig. 5, are operated by live steam controlled by three-way cocks from the throttle or the roller's pulpit. When the engine is first started these valves are opened, the condensate and exhaust being piped to the main exhaust on

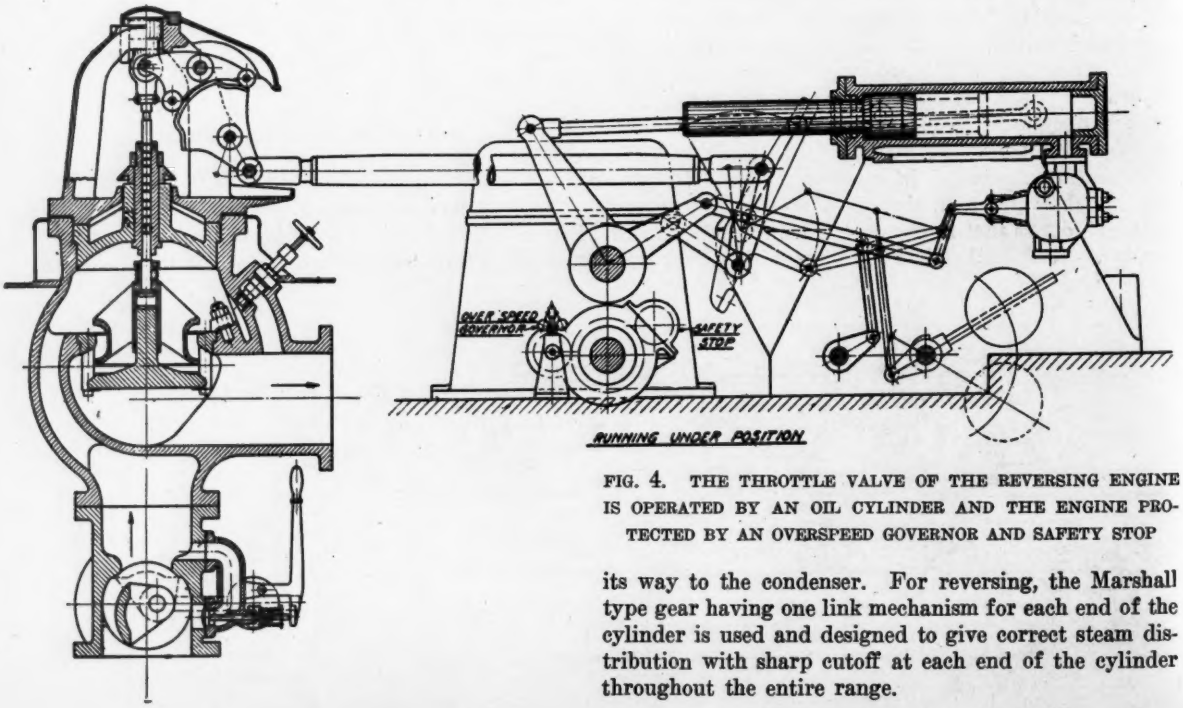


FIG. 4. THE THROTTLE VALVE OF THE REVERSING ENGINE IS OPERATED BY AN OIL CYLINDER AND THE ENGINE PROTECTED BY AN OVERSPEED GOVERNOR AND SAFETY STOP

its way to the condenser. For reversing, the Marshall type gear having one link mechanism for each end of the cylinder is used and designed to give correct steam distribution with sharp cutoff at each end of the cylinder throughout the entire range.

PRINCIPAL DIMENSIONS OF ENGINES

Drives	35-in. reversing mill	19-in. continuous mill
Engine cylinders, dia. x stroke, in...	36x60	36x60
Steam pressure, lb. gage.....	240	240
Superheat, deg. Fahr.....	125	125
Vacuum, in. absolute	4	4
Speed, r.p.m., normal max.....	150	75
Main bearings, five, dia. x length, in.	22x28	22x28
Outboard bearing, dia. x length, in	.....	23x36
Crank pins, dia. x length, in.....	21x16	21x16
Crosshead pins, two per cyl., in....	9x 8¾	9x 8¾
Crosshead shoes, in.....	20x33	20x33
Tail guide shoes, in.....	18x21	18x21
Piston rods, hollow, dia., in.....	10	10
Steam pipe, dia., in.....	14	14
Exhaust pipe, dia., in.....	20	20

WEIGHTS IN POUNDS

Engine complete	950,000	1,000,000
Main bedplate	240,000	160,000
Crank shaft, complete	160,000	165,000
Crosshead slides, each	37,000	37,000
Tail guides, each	8,500	8,500
Cylinder barrels, each	26,000	26,000
Cylinder heads, each	2,000	2,000
Piston and hollow piston rod.....	7,000	7,000
Crossheads, each	3,000	3,000
Connecting rods, hollow, each.....	9,500	9,500
20 ft. flywheel, four sections.....	.....	75,000

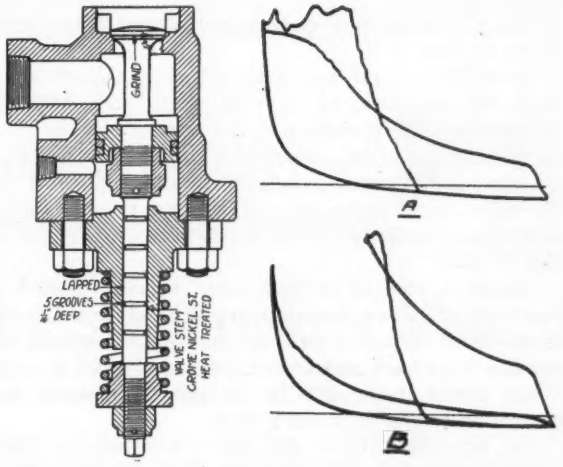


FIG. 5. ALL CYLINDERS ARE DRAINED BY AUTOMATIC DRAIN VALVES. ACTUAL INDICATOR CARDS SHOW ACTION OF ENGINE WHILE REVERSING

Engine speed is controlled entirely by the cutoff through two double acting hydraulic cylinders shown on top of the crosshead guides in Fig. 3. These are located side by side and worked by oil pressure at about 150 lb. per sq. in., oil being supplied by motor driven pumps with an accumulator used in the system to maintain constant pressure. Motion of these operating cylinders is controlled by pilot valves, in the case of the reversing engine, operated manually from the roller's pulpit or

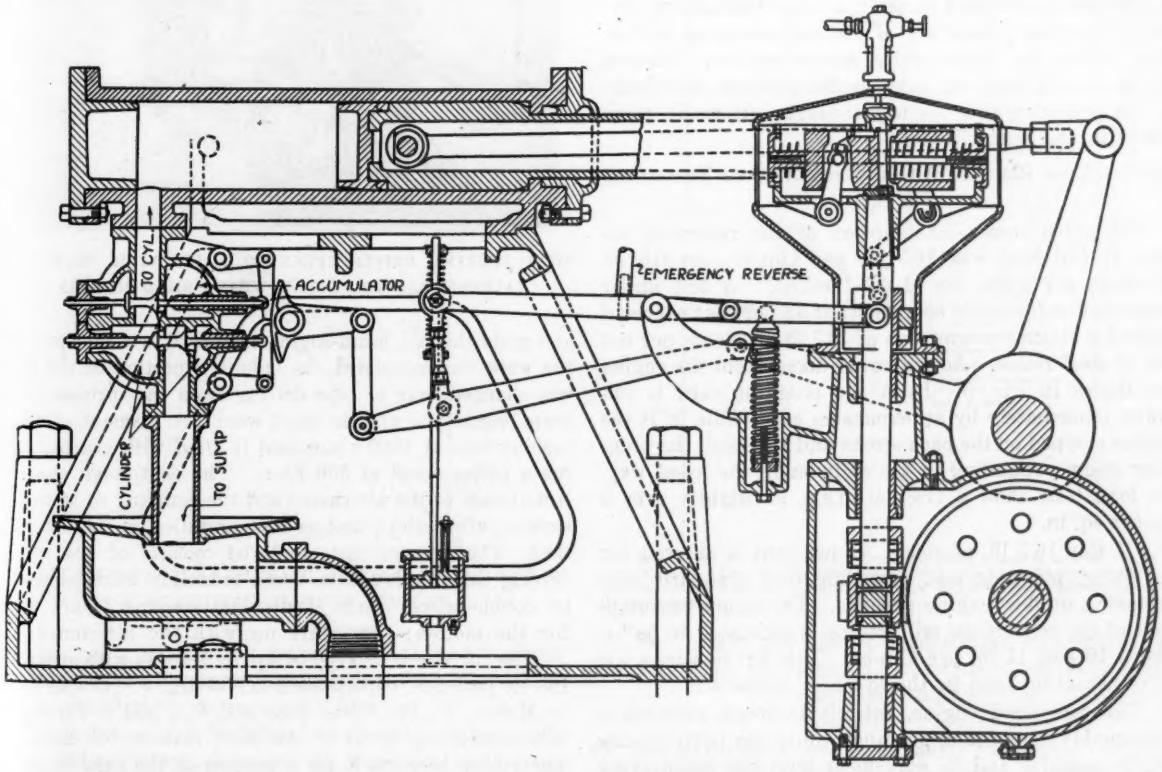


FIG. 6. THE CONTINUOUS MILL ENGINE SPEED IS CONTROLLED BY A GOVERNOR OPERATING THE OIL PRESSURE PILOT VALVES

on the continuous mill engine by the governor control shown in Fig. 6.

Movement of the hydraulic cylinders follows absolutely the movement of the pilot valves and operating lever. When the operating lever comes to rest the pilot valves are both closed, effectively locking the operating cylinders in position. It is mechanically impossible for both pilot valves to be open at the same time as can be seen from the detail of the mechanism in the left of Fig. 6.

Steam is brought in from below between number 2 and 3 cylinders to a throttle valve and distributed to the steam chests through a built-up manifold. A special expansion joint machined from a solid steel block is used. When tested under 300 lb. hydrostatic pressure the elongation of this joint was 5/32 in.

All running parts of the engine are pressure lubricated from a 2400-gal. overhead tank. Oil flows from the end of the crankshaft through drilled passages and grooves to reach all wearing parts of the main bearings, crankpins, wrist pins and crosshead shoes. A second line lubricates the reversing gear. All used oil is drained into the crankpit from where it flows by gravity to a filter to be pumped again to the overhead tank. A gage located at the level of the bearings indicates an oil pressure of 12 lb. Six point Richardson-Phenix lubricators are furnished for each cylinder, one point lubricating the cylinder, one the valve and one the metallic packing on each end of each cylinder.

Steam is condensed in special barometric condensers designed to handle pulsating flows. Water storage capacity is provided and a pan arrangement similar to a feed-water heater used to offer a large condensing surface. Vacuum pumps are of the reciprocating uniflow type driven by piston valve steam engines. Suction valves are not used, air entering the ports in the middle of the cylinder and leaving through automatic plate valves in the heads.

Actual Test Results Agree Closely with Estimated Figures

Estimated steam consumption of the reversing engine at full load was 16.3 lb. per i.hp-hr., or 315 lb. of steam per gross ton of steel rolled. A test under somewhat unfavorable conditions at 33 per cent overload showed a steam consumption of 317 lb. of steam per net ton of steel rolled. Actual cards taken from the engine are shown in Fig. 5. In A the plugging card is followed immediately by an expansion card while in B the engine stopped on the back stroke and reversed, the plugging steam expanding in the cylinder in the usual way. No load tests show a friction m.e.p. of slightly over 2 lb. per sq. in.

Of this 16.3 lb. of steam, 44 per cent is allowed for reversing, plugging and throttling over standard non-reversing uniflow engine practice. The steam consumption of the continuous mill engine is estimated to be between 10 and 11 lb. per i.hp-hr. This figure allows for the fluctuating load in the cycle of operation.

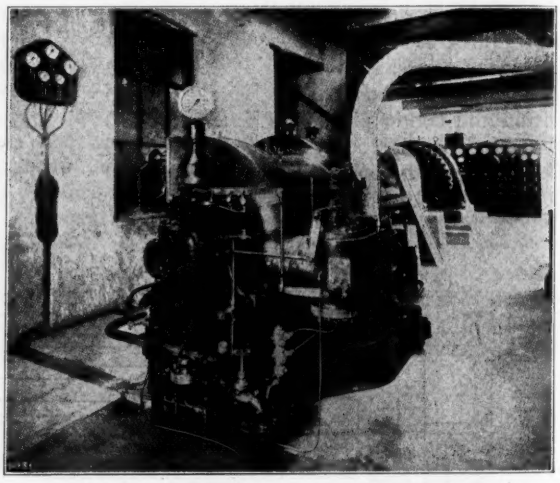
The completed engine, entirely enclosed, presents a remarkably compact appearance while the performance of the machine and its agreement with the engineering estimates, far in excess of anything ever before attempted, shows the high state of development of modern engine practice.

Turbine Drives Cotton Mill with Rope and Motors

Rope Drive Pulley and Alternator Driven Through Gearing; Weave Shed Motors Start with Alternator

AN INTERESTING combined rope and electric drive from a single prime-mover was installed at the end of last year at the Rishton Victoria Cotton Mill, Rishton, England, near Blackburn. The original plant at the mill consisted of a double-beam engine of 900 i.hp., built in 1860, which drove the spinning mill through spur gearing and an upright shaft, a horizontal engine driving the weaving shed through bevel gears. When it was decided to modernize the drive, says Engineering of London, various schemes of conversion were considered, including reciprocating engines and all-electric driving. It was finally decided, however, to install a single steam-turbine unit with a combined drive.

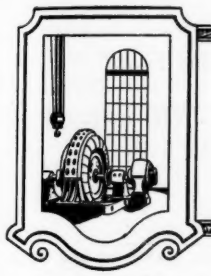
The turbine and its rope pulley were installed in a small space between the mill chimney and the mill, and



THIS TURBINE DRIVES SPINNING MILL WITH ROPE AND ALTERNATOR TO SUPPLY WEAVE SHED MOTORS

alongside the old beam-engine house. When this part of the work was completed, the spinning portion of the mill was changed over to rope driving from the turbine. The beam engine and upright shaft were then dismantled. The turbine runs at 4800 r.p.m. and is fitted with gearing giving a pulley speed of 500 r.p.m. The next stage was the installation of the alternator and the coupling of it to the turbine, after which motors were installed in the weaving shed. The arrangement employed consists of one motor driving three cross-shafts, speed reduction being obtained by double-helical gears. Individual starting is not used for the motors; they start up with the alternator.

The turbine is of 1750 br.hp. and works with steam at 160 lb. pressure, superheated to 650 deg. F. It was built by Messrs. W. H. Allen, Sons and Co., and is furnished with condensing plant by the same makers, but arrangements have been made for a portion of the exhaust to be utilized for heating purpose. The waste steam from the air pump is utilized for heating the feed before it enters the economizer.



ELECTRICAL MACHINERY FOR LIGHT AND POWER

Power Factor Correction by Synchronous Motors

PRINCIPLES INVOLVED IN CORRECTING POWER FACTOR. METHODS OF CALCULATION AND SOLUTION OF PROBLEMS BY MEANS OF VECTOR DIAGRAMS. BY A. S. RUFSVOLD*

WITH THE REALIZATION of the importance of maintaining high power factor on alternating current circuits the application of the synchronous motor for the improvement of power factor is constantly receiving more attention. The principles involved in the selection of the proper synchronous machinery are not difficult, and a proper understanding of these principles will enable the layman to handle power factor problems with a considerable degree of intelligence.

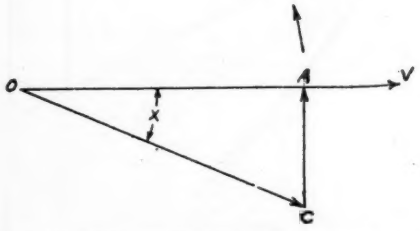


FIG. 1. GRAPHIC REPRESENTATION OF POWER FACTOR

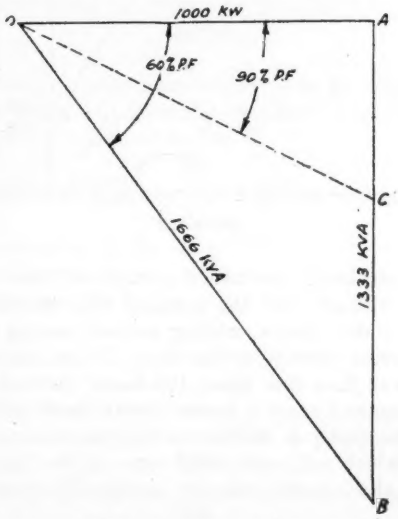
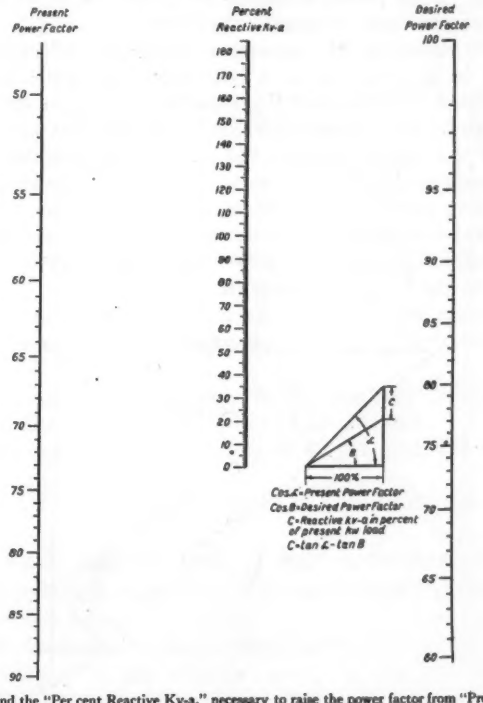


FIG. 2. AN EXAMPLE, SHOWING METHOD OF SOLVING A POWER FACTOR CORRECTION PROBLEM

Power factor may be defined as the ratio, in per cent, of the actual power expressed in kilowatts to the apparent power expressed in kilovolt-amperes. For example, if wattmeter readings indicate 750 kw. in a circuit and voltmeter and ammeter readings indicate 1000 kv.a., then the power factor of the circuit is 75 per cent.

In any alternating current circuit having a power factor less than 100 per cent, the peak of the current wave does not occur simultaneously with the peak of the voltage wave, and the current either leads or lags the voltage by a definite angle. An inductive load, as from induction motors, will cause a lagging current. This is the case to consider for power factor correction. Referring to Fig. 1, OV represents the voltage and OC the current flowing in the circuit. With the direction of phase rotation as shown, the current lags the voltage


Present Power Factor
Percent Reactive Kv-a
Desired Power Factor
100%
Cos A = Present Power Factor
Cos B = Desired Power Factor
C = Reactive kv-a in percent of present kw load
C = tan A - tan B

To find the "Per cent Reactive Kv-a." necessary to raise the power factor from "Present Power Factor" to "Desired Power Factor," lay a straight edge across the chart connecting these two values. Read the "Reactive Kv-a." in per cent of the present kilowatt load on the middle scale.

FIG. 2A. CHART FOR USE IN DETERMINING THE PER CENT REACTIVE KV.A. REQUIRED TO RAISE THE POWER FACTOR TO A DESIRED VALUE

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by the angle X. The current vector OC may be considered as made up of two components, the useful component OA, in phase with the voltage, and the lagging reactive component AC, 90 deg. out of phase with the voltage. The power factor of the circuit is OA divided by OC, or the cosine of the angle X.

In like manner, Fig. 1 may be considered as a power triangle, OA representing the true power in kilowatts, OC representing the apparent power in kilovolt-amperes, and AC representing the lagging reactive kilovolt-amperes. Such power triangles are made use of in working power factor correction problems.

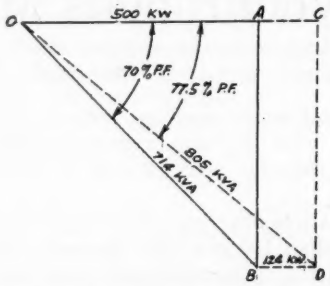


FIG. 3. SOLUTION OF A POWER FACTOR CORRECTION PROBLEM WITH AN ADDED MOTOR LOAD

To determine the amount of corrective effect necessary in a given case is a comparatively simple matter provided the following fundamental principles are kept in mind: the reactive current is 90 deg. out of phase with the useful current; the leading and lagging components are in direct phase opposition, and the resultant reactive component is the algebraic difference; the resultant current is the vectorial sum of the reactive and useful components; the power factor is the ratio of the kw. to the kv.a. in the circuit.

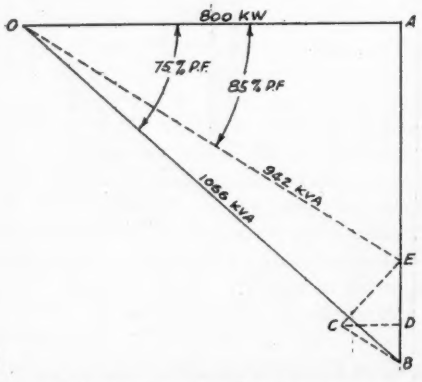


FIG. 4. A PROBLEM SIMILAR TO THAT SHOWN IN FIG. 3 BUT WITH A SYNCHRONOUS MOTOR REPLACING THE INDUCTION MOTOR

A typical example would be as follows: It is desired to bring up to 90 per cent power factor, a load of 1000 kw. operating at 60 per cent power factor. To this end it is necessary to know the total kv.a. the reactive kv.a., and the reactive kv.a. necessary to bring about the required charge in power factor from 60 to 90 per cent.

Referring to Fig. 2

$$\text{Total kv.a. (OB)} = \frac{1000}{0.6} = 1666 \text{ kv.a.}$$

Reactive kv.a. (AB) $= \sqrt{1666^2 - 1000^2} = 1333$ kv.a.

For 90 per cent power factor, total kv.a. (OC) must be $\frac{1000}{0.9} = 1111$ kv.a.

Reactive kv.a. (AC) $= \sqrt{1111^2 - 1000^2} = 484$ kv.a.

Corrective kv.a. (BC) necessary is $1333 - 484 = 849$ kv.a.

Problems of this type which do not involve the addition of kw. load can be readily solved by means of the chart shown in Fig. 2a, which is self explanatory.

A synchronous motor has a field winding excited by direct current, and its internal power factor is determined by the amount of excitation. At a certain value of field excitation the motor current will be in phase with the voltage, and the machine will operate at 100 per cent power factor, adding neither leading nor lagging reactive current to the line. If the excitation is made lower than this value, the motor current will lag the voltage and cause a poorer power factor on the line. But if the motor is over-excited it will draw a leading current which will correct for some of the lagging current in the circuit, thereby raising the total power factor.

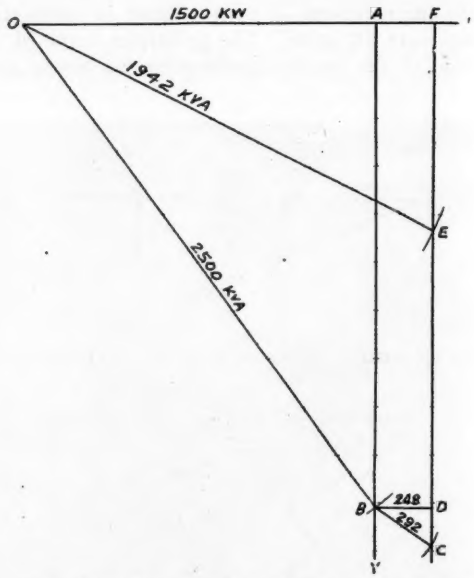


FIG. 5. GRAPHIC SOLUTION OF A POWER FACTOR CORRECTION PROBLEM

A synchronous motor may be designed and rated to operate at any power factor between 100 per cent and 0 per cent leading. If designed for 100 per cent power factor operation, its application would merely add a certain unity power factor load without correcting for any of the existing lagging reactive kv.a. in the circuit. In the case of an 80 per cent power factor synchronous motor there would be available $\sqrt{100^2 - 80^2} = 60$ per cent of its kv.a. capacity for corrective effect. Some machines are designed for power factor correction only and do not carry any mechanical load. Such a machine

operates at 0 per cent power factor and is termed a synchronous condenser. A specific example of each case will illustrate, first by the addition of a 100 per cent power factor motor, and second by replacing an induction motor by a synchronous motor. Assume in the first example that there is a total load of 500 kw. with a power factor of 70 per cent. A 150-hp. 100 per cent

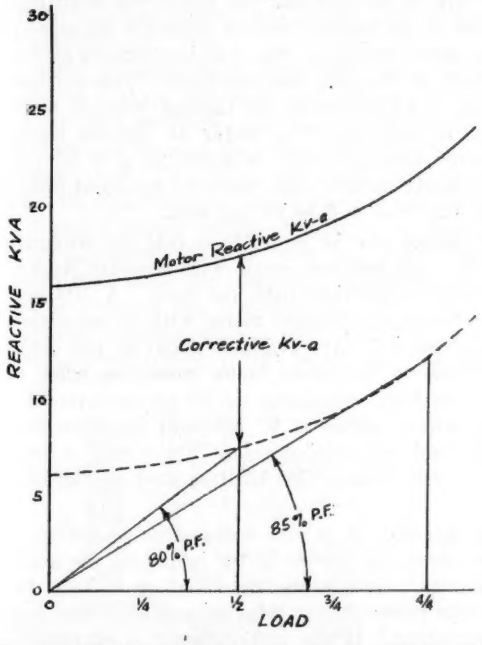


FIG. 6. SHOWING THE EFFECT OF POWER FACTOR CORRECTION AT DIFFERENT LOADS ON A 50-HP., 10-POLE, INDUCTION MOTOR

power factor synchronous motor is to be added. The solution below will give the resultant total kv.a. and power factor, referring to Fig. 3,

$$\text{Total kv.a. (OB)} = \frac{500}{0.7} = 714 \text{ kv.a.}$$

$$\text{Reactive kv.a. (AB)} = \sqrt{714^2 - 500^2} = 510 \text{ kv.a.}$$

Assuming the motor efficiency is 90 per cent, the additional load (BD) due to the motor is

$$\frac{150 \times 0.746}{0.9} = 124 \text{ kw.}$$

Solving the new triangle,

$$\text{New total kv.a. (OD)} = \sqrt{624^2 + 510^2} = 805 \text{ kv.a.}$$

$$\text{New power factor} = \frac{624}{805} \times 100 = 77.5 \text{ per cent.}$$

In the second example a total load of 800 kw. with original power factor of 75 per cent is assumed. A synchronous motor is to replace a 150-hp. induction motor and furnish sufficient reactive kv.a. to raise the power factor to 85 per cent. It becomes necessary, then, to find the kv.a. and power factor rating of the motor. Assume the following:

Synchronous motor efficiency = 90 per cent.
Induction motor efficiency = 90 per cent.
Induction motor power factor = 85 per cent.
Referring to Fig. 4,

$$\text{Original kv.a. (OB)} = \frac{800}{0.75} = 1066 \text{ kv.a.}$$

$$\text{Original reactive kv.a. (AB)} = \sqrt{1066^2 - 800^2} = 705 \text{ kv.a.}$$

$$\text{kw. load (CD) due to induction motor} = \frac{150 \times 0.746}{0.90} = 124 \text{ kw.}$$

$$\text{kv.a. input (BC) of induction motor} = \frac{150 \times 0.746}{0.90 \times 0.85} = 146 \text{ kv.a.}$$

$$\text{Reactive kv.a. (BD) of induction motor} = \sqrt{146^2 - 124^2} = 77 \text{ kv.a.}$$

Total reactance kv.a. (AD) with induction motor removed = 705 — 77 = 628 kv.a.

Since the synchronous motor is of the same horse-

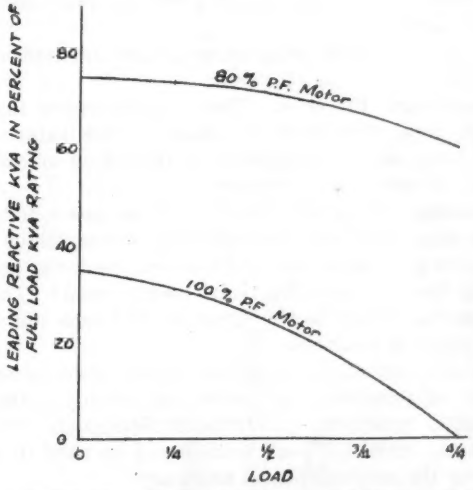


FIG. 7. SHOWING THE VARIATION IN CORRECTIVE CAPACITY WITH LOAD, ASSUMING CONSTANT FIELD EXCITATION

power rating and efficiency as the replaced induction motor, the total kw. load will not be changed.

For resultant power factor of 85 per cent, the total kv.a. (OE) must be $\frac{800}{0.85} = 942$ kv.a. and total reactive kv.a. (AE) must be $\sqrt{942^2 - 800^2} = 496$ kv.a.

Therefore, corrective kv.a. necessary (DE) is 628 — 496 = 132 kv.a.

$$\text{kw. load due to synchronous motor} = \frac{150 \times 0.746}{0.90} = 124 \text{ kw.}$$

Then the kv.a. rating of the synchronous motor (CE) will be $\sqrt{124^2 + 132^2} = 181$ kv.a. and the power factor rating will be $\frac{124}{181} \times 100 = 68.5$ per cent.

The preceding examples were worked numerically. The next example is solved graphically, which method is preferred by many and is sufficiently accurate for most purposes.

With a load of 1500 kw. at 60 per cent power factor, it is desired to install a 300-hp. induction motor and a synchronous condenser to correct the power factor to 90 per cent. It is necessary to find the rating of the synchronous condenser.

Assume induction motor efficiency = 90 per cent.

Assume induction motor power factor = 85 per cent.

Referring to Fig. 5, lay out OA to scale representing 1500 kw. and draw the perpendicular AY.

With O as a center, strike an arc at a radius corresponding to the total reactive kv.a., which is $\frac{1500}{0.6}$ or 2500 kv.a. From B construct the triangle BCD in a similar manner, representing the induction motor load which is to be added, with BD corresponding to $\frac{300 \times 0.746}{0.9}$ or 248 kw., and BC corresponding to $\frac{248}{0.85}$ or 292 kv.a. Then CF represents the total reactive kv.a. Now with O as a center and at a radius corresponding to $\frac{1500 + 248}{0.9}$ or 1942 kv.a., strike an arc intersecting the perpendicular FC at E. Then CE represents the corrective kv.a. that must be added. This value scales 1310 kv.a., which corresponds to the rating of the necessary synchronous condenser.

Before making calculation it is necessary to determine what load and corresponding power factor shall be taken as a basis. Should the peak load, the average yearly load, or some fractional load be used? There is no general answer to this question, and each individual case must be analyzed.

From the standpoint of the power plant owner, recovery of generating and switching capacity is the fundamental reason for power factor correction. On this basis the sustained peak load should be used in determining the corrective kv.a. necessary.

From the standpoint of the power consumer, the main reason for power factor correction is to avoid penalty or otherwise effect a saving in the power bill. In this case it is generally necessary to keep the power factor above a certain specified value. It is quite likely that the poorest power factor condition will occur at light load rather than at peak load. If the decrease in load is due to a lighter load on the induction motors which are on the line and not due to the shutting down of some of the motors, then to maintain the same power factor, more corrective kv.a. will be required at the light load than at the peak load condition. This is illustrated by Fig. 6, which shows the lagging reactive kv.a. of a 50-hp. 10-pole induction motor at various loads. If sufficient corrective kv.a. is added to give 80 per cent power factor at half load, then the resultant power factor at full load will be 85 per cent.

It should also be understood that the corrective effect of a synchronous motor with constant field excitation varies somewhat with the load. A 100 per cent power factor synchronous motor with no corrective kv.a. at full load will have available about 35 per cent of its kv.a. capacity for power factor correction when operating at no load. Similarly, an 80 per cent power factor motor which furnishes 60 per cent in corrective kv.a. at full load will furnish about 75 per cent in corrective kv.a. at zero load. This is illustrated by the curves of Fig. 7.

In general, it is not economical to correct power factor above the power factor rating of the generating equipment. Generators are rated on a kv.a. basis at a certain power factor, whereas prime-movers are given a kw. rating. If the power factor is corrected above that of the generator rating, the generator will be capable of carrying a greater kilowatt load, but it will usually be found that the prime-mover cannot be overloaded to meet the new condition. This point should be carefully checked before considering the correction of power factor above that of the generator rating.

Carrying Capacity of 60-Cycle Busses*

Results of Series of Tests Made to Determine Efficient and Practicable Bus Construction for High Currents. By Titus G. Le Clair†

UNTIL WITHIN recent years it has seldom been necessary to design busses for current carrying capacities above 2000 or 3000 amp. In consequence of the increasing use of electricity in industrial processes it has become necessary now to design busses far beyond the old limits and the time is not far distant when we shall need to carry 10,000 amp. or more on a single bus.

In any d.c. circuit, be the conductor solid, laminated or stranded, the current divides in all parts in proportion to the resistance which means that with a conductor of homogenous material, the current is practically the same in all parts. The same condition does not hold true, however, for alternating current. In addition to the resistance drop, an alternating current introduces an alternating flux surrounding any element of the conductor. This alternating flux generates a voltage which tends to oppose the flow of current in the conductor element. When we consider a large conductor, it is obvious that the lines of force caused by an element in the outer part surround the entire conductor, but for a central element, some of the flux does not cut the outer elements. The result is that the effective impedance of an element in the central part of the copper is higher than in the outer edge, thereby forcing most of the current to the outer surface, producing the so-called skin effect. In extremely large conductors this can be carried so far as to have the current in the center of the bus nearly in the opposite direction to the current in the outer part of the bus as well as being smaller in magnitude.

When the phases are placed close together there is, in addition to the skin effect, a voltage induced by the flux from an opposite phase which is not uniform over the entire conductor and forces current towards the side. This is called the proximity effect. Both skin effect and proximity effect can be calculated for cylindrical or tubular conductors.

*Abstract of a paper delivered before the American Institute of Electrical Engineers.

†Engineer, Commonwealth Edison Co., Chicago, Ill.

Since it is impractical to use circular conductors for large busses it has been the practice to use laminated copper busses. For a bus of this shape, however, it is impracticable to calculate the distribution of currents in order to obtain the temperature rise.

Method of Conducting Tests

A series of tests were made, therefore, to determine an efficient and practicable type of bus construction for high currents.

In order to make these tests applicable to heavy currents and 3-phase circuits, a 3-phase bus, 20 ft. long was set up and connected in the circuit between the transformer and three of the rings of a 3900-kw., 230-v., rotary converter. This converter could be operated in parallel with another machine on the d.c. side and permitted a ready control of the current up to quite high values. Practically all tests were run with constant current to determine the ultimate temperature rise of the various types of bus construction.

Temperature measurements were made by means of thermocouples connected to the centers of the various

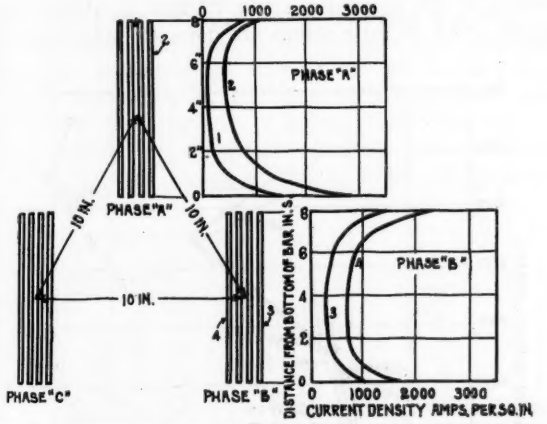


FIG. 1. CURRENT DISTRIBUTION IN A THREE-PHASE BUS, CONSISTING OF FOUR 8 BY ¼-IN. COPPER BARS PER PHASE AT 4000 AMP. PER PHASE

bars in this 20-ft. section. Impedance voltage drop was measured by means of straight leads perpendicular to the bus, carried far enough away to be out of the influence of the magnetic circuit.

In addition to these measurements, the current in various parts of individual conductors was also determined and to eliminate end effects, only the central 15 ft. of bus were used.

We have found a number of things which enter into the construction of a bus that are not constant for all circuits. For example, the current distribution will be very different on single-phase from that on three-phase circuits. Also, there is an extremely great difference between isolated-phase and group-phase busses due to proximity effect.

The majority of engineers are not particularly interested in the exact distribution of current in various parts of the bus. The primary question which enters the designer's mind is rather how much copper he must use and how he may best use it. A concrete example of the distribution of current will, however, clarify ideas of the results of skin effect and proximity effect and help a great deal in deciding for a particular case what form should be used. In Fig. 1 is shown a three-phase bus, each phase consisting of four 8-in. by ¼-in. bars per phase with phases set in an equilateral triangle on ten-inch centers. It will be noted that the current in *A* phase bus is practically all in the very bottom edge of the bars, and the usefulness of the upper half of the bar is more in the nature of a radiator than a conductor.

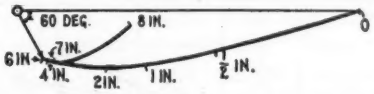


FIG. 2. POLAR DIAGRAM OF CURRENT DISTRIBUTION IN OUTER SURFACE OF 8 BY ¼-IN. BAR

Figures refer to distances from bottom edge of bar. The surface considered is the same as curve 2 in Fig. 1.

For this reason a bus of similar construction, except made of four-inch bars in the same layout, that is, four bars wide and two bars high, would not be nearly so effective because the upper set of bars would not carry much current, and in addition would have poor heat connection to the lower bars. Hence, they would not serve as good radiators.

It may also be interesting to note in Fig. 2 the relation of the phase angle of current in various parts of the bar. It will be seen that the current at the minimum point lags 60 deg. behind that in the lower edge and that the point of minimum current is 6 in. instead of 4 in. from the bottom of the bar. As we go nearer

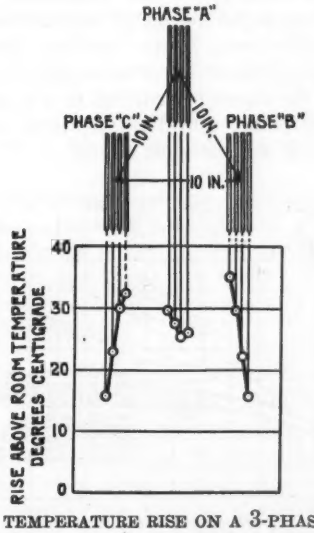


FIG. 3. TEMPERATURE RISE ON A 3-PHASE BAR

Consisting of four 8 by ¼in. bars per phase under a continuous load of 4000 amp. per phase. Bus mounted in still air not enclosed.

to the center of the bus, the current lags farther behind that in the outer edge of the outer conductor until we find the current at the center is very nearly 180 deg. out of phase. As a striking example, in a bus *consisting of four bars laid on the sides of a rectangle, the addition of a fifth bar in the center actually increased the losses and temperature rise for the same current.* In an article by C. F. Wagner on this same subject, for single-phase busses he draws the curve from the outer edge to the center of the bar, and assumes that the same condition holds from the center to the opposite edge of a bar. This

is perfectly true in some cases but not at all true in others, and the electrical center, or the point of minimum current in a bar, may not be the physical center.

If we now look at Fig. 3 to get the temperature rises of the various bars and consider that the temperature rise is proportional to the square of the current, we get a somewhat erroneous impression, due to the fact that while the central bars may be carrying some current,

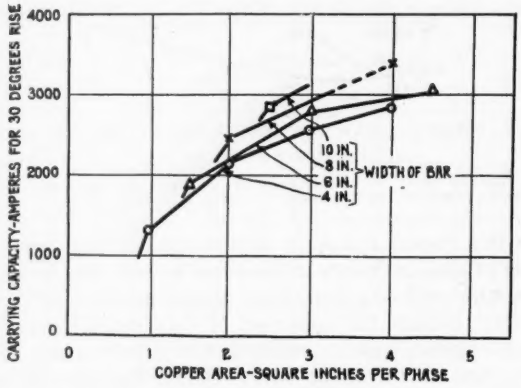


FIG. 4. ELECTRIC POWER CLUB STANDARDS

Ratings of laminated busses on grouped phases up to 3000 amp. at 60 cycles. Centers on a straight line with 8 in. between phases and ¼ in. spacing between laminations.

this is not a measure of their effectiveness, because as stated before the current in the central bar may be sufficiently out of phase to be of little or no value.

For moderate currents the important item in the design of a bus is the matter of ventilation. When we come to consider very heavy currents, this matter of ventilation is of minor importance, since ventilation is useless if all the current is carried in a small portion of the bus. The prime consideration, then, is to put the copper where it will be most useful.

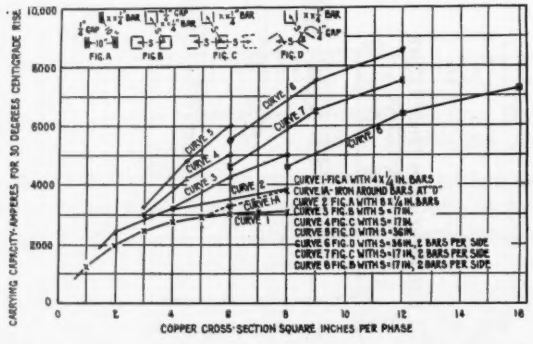


FIG. 5. RATINGS OF BUSSES ON GROUPED PHASES ABOVE 3000 AMP. AT 60 CYCLES

All bars are ¼ in. thick by 4, 6 or 8 in. wide. For instance, the center points on curve 6 represent six bars of 6 by ¼ in. copper and the upper point on the same curve means six bars of 8 by ¼ in. copper.

There are very few data available at this time on the carrying capacity of busses for heavy current. For example, some operating companies have for many years used the standard of 1000 amp. per sq. in. of copper section. This gives ample copper for busses up to 2000 amp., but beyond this point the rule no longer holds. For isolated phases, the General Electric Co. has worked out a system of busses* which is not at all difficult to mount and is very satisfactory for currents up to 7400 amp. at 60 cycles. Due to the proximity effect as shown in the test data, it is obvious that this type of bus construction would be of little value for group phases on very close centers since the current would all be thrown into one corner of the bus and would cause it to run very hot. The Electric Power Club has given as a standard Fig. 4, which is for group phases up to 3000 amp. Beyond this point we have compiled from our test data the curves in Fig. 5 for special types of bus construction. The curves do not, of course, give all the data required for any particular installation, but they give the points necessary for determining what should be used.

In Fig. 5, Curve 7 gives the rating of *C* on 17-in. centers. If the phases are separated further, the ratings of these busses will be raised somewhat but not so high as Curve 6. Curve 6 gives the rating of *D* on 36-in. centers, and the rating of this bus would be lower on the closer centers but not so low as Curve 7. In Curve 8 the rating may be very materially increased by one or both of two methods, either by a wider opening of the corners of the rectangle, or by further separating the phases. If both these things are done, we may obtain a

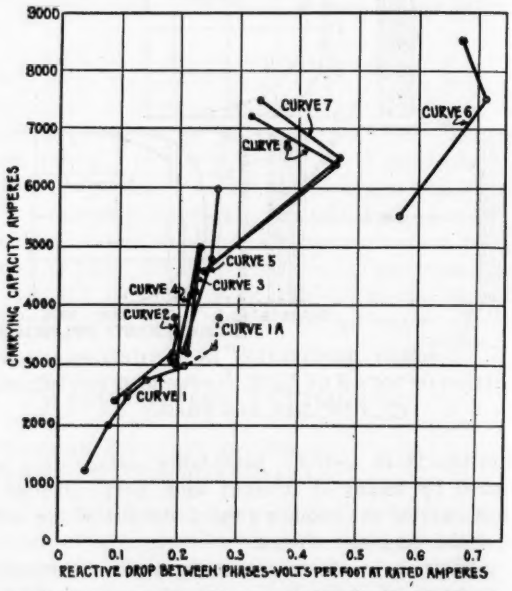


FIG. 6. REACTIVE VOLTAGE DROP ON 3-PHASE BUSSES

Curve numbers and points refer to corresponding curve numbers and points for busses shown in Fig. 5. With phases arranged with centers on the same straight line, the average drop will be about 25 per cent higher and the drop in the two outer phases will be higher than that in the center phase.

bus of perhaps higher carrying capacity than that given in Curve 6. When the space limitations or the allowable reactive drop does not demand that phases be on the corners of an equilateral triangle, the dotted arrangement shown in *C* is practically equivalent in carrying capacity to that of *D*.

Up to about 3000 amp. the reactance of the bus is not of very great importance, but beyond this point and especially for low voltages it becomes a serious item. For instance, on a bus carrying 6000 amp. at 230 v. and

*General Electric Bulletin No. 87000-D, Sept. 1924, p. 26.

only 30 ft. long, it may be readily seen from Fig. 6 that the reactive drop may be from 3 per cent to 8 per cent of line voltage. This, in addition to the reactance of feeders, may cause a very poor voltage regulation at low power factors unless care is used in the selection of the bus.

Another important point in the matter of reactance is that it is frequently necessary to parallel transformer banks of different sizes or with different lengths of copper from the banks to the point of paralleling. For large transformers the bus reactance is considerable compared to the transformer reactance and up to the point of paralleling, the bus reactance may be considered a part of the transformer reactance so far as division of load is concerned. This effect is especially noticeable where transformer banks of different capacities are paralleled, because the percentage reactance per foot is very much higher for large than for small busses. Sometimes it even becomes necessary to install a reactance in series with the smaller transformer bank to prevent overheating of one bank when the other is not fully loaded.

In Curve 1-*A*, Fig. 5, is shown the carrying capacity of a laminated bus, balanced with magnetic steel, as proposed by Mr. Wagner. It is true that the addition of this magnetic steel does increase the carrying capacity. However, the amount of iron to be added must be determined by the cut-and-try method for any installation and the cost of adding this balancing becomes prohibitive, especially when the class of labor usually employed knows nothing of what is to be done.

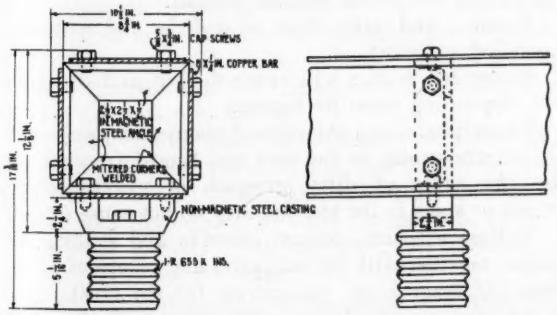


FIG. 7. FORM OF BUS SUPPORT FOR RECTANGULAR BUSSES REQUIRING DRILLING OF COPPER ON JOB. NO CLAMPS REQUIRED

The principal objection to the use of a rectangular form of bus is the same as one of the objections to the tubular form of bus; that is, the difficulty of mounting; however, a little careful consideration will show that the rectangular bus is not particularly difficult to mount since flat clamps may be used which are very similar to those used for an ordinary laminated bus.

The manner of making taps is little more difficult than with the ordinary laminated bus because all the copper surfaces are flat. Especially is this true if the corners of the rectangle are left open, making room to handle bolts inside. The necessary bracing between phases may be attached to the clamps in practically the same way as is done with laminated busses. We have added two preliminary sketches of supports, (Figs. 7 and 8). The type which is cheapest to use depends a good deal upon the type of labor employed. Where skilled and experienced labor is used on the job, Fig. 7 requires less material and would probably be cheapest to install. Where the labor is not particularly skilled or fast, or where labor costs are high, Fig. 8, although it requires more material, takes little time to mount and would not be as expensive per ampere of current carried as the clamp now used for laminated busses. Neither one of these supports is particularly difficult to handle, nor is it particularly difficult to make taps to this bus since there is room for strap copper or lug connections on the surface of every bar. When these supports are used on the form of bus shown in Fig. 5C, the bar nearest the support may be omitted without changing the method of mounting.

In presenting this paper we have hoped to give a ready reference through which engineers may choose the type of bus best adapted for their needs without any involved calculations which they have neither time nor inclination to make. In conclusion, let us state that although the Electric Power Club Standards call for the maximum of 30 deg. cent. temperature rise and the

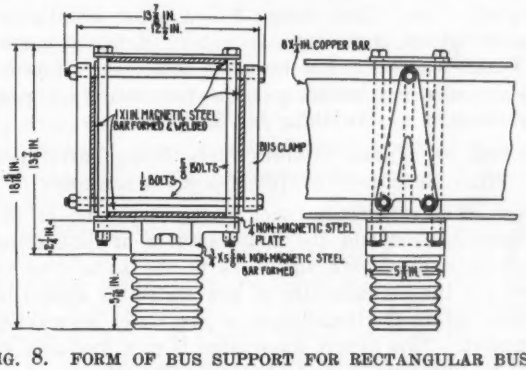


FIG. 8. FORM OF BUS SUPPORT FOR RECTANGULAR BUSSES REQUIRING NO JOB DRILLING OF COPPER

busses given are designed on this basis, nevertheless, a number of years' experience has shown that a 40-deg. temperature rise gives no trouble due to oxidation when reasonably good connections are made. Especially is this true when the ambient temperature is nearer to 25 deg. than to 40 deg. cent.

Discharging Storage Batteries

HEAVY OVER-DISCHARGE rates maintained for a considerable time are almost sure to injure the cells. The normal discharge rate should not be exceeded except in cases of emergency. The amount of charge remaining available at any time can be determined from voltage and specific gravity readings. During the greater part of a complete discharge, the drop in voltage is slight and very gradual, but near the end the falling off becomes much more marked. Under no circumstances should a battery ever be discharged below 1.7 v. per cell, and in ordinary service it is advisable to stop the discharge at 1.75 or 1.8 v. If a reserve is to be kept in the battery for use in case of emergency, the discharge must be stopped at a correspondingly higher voltage. The fall in density of the electrolyte is in direct proportion to the ampere-hours taken out and is, therefore, a reliable guide as to the amount of the discharge.

Water Treatment for Raw Water Ice Plants

Removal of Various Compounds of Calcium and Magnesium, Together with Iron and Organic Matter, Allows Clear Ice to be Made with Less Power. By W. N. Waterman

WHEN THE manufacture of artificial ice from raw water, instead of distilled water, was just begun, it was thought that clean, clear water was all that was necessary to make first-quality ice. This early opinion resulted from the fact that the first ice plants installed for the manufacture of raw water ice, produced merchantable ice without water treatment. It happened, however, that these first plants were installed in soft water districts where only the removal of suspended matter was necessary and the conclusion was that filtration only was required.

After several plants had been installed, however, using well water which was so clear that filtration could remove nothing from it, but where the ice was of such poor quality as to be hardly merchantable, a readjustment of these early ideas became necessary. The next theory was advanced that any soft water would make first-quality ice. This theory failed after installation of several plants in the artesian water districts of northern Texas, where the water was so soft that it formed no scale in steam boilers yet the raw water ice produced from it was anything but first quality.

Analysis of Water Conditions is More Important Than Selection of Ice-Making Machinery

Numerous experiences such as these proved to the ice manufacturer and the manufacturer of ice-making machinery that expert advice as to the suitability of waters for the manufacture of raw water ice should be obtained before the installation of raw water ice-making equipment. This expert knowledge is now available to every ice machine manufacturer and every ice plant and the quality of ice that can be expected of any water can be accurately prophesied after a special analysis of the water and the conditions.

The first question to be decided by the prospective raw water ice manufacturer should be not what kind of machinery to buy, but whether the available water supply is suitable for the manufacture of high-quality ice. His first step should be to submit a sample of the water supply to an organization capable of making the proper analysis of the water and whose training and experience in this particular problem has made it familiar with the thousand and one different conditions that occur in different ice plants.

Unless the water is suitable for raw water ice, the raw water ice-making equipment will be useless. As an example of placing the cart before the horse, there is the experience of a plant in one of the western states where the raw water ice-making machinery was purchased and installed before the well was drilled. The well delivered plenty of hot water of good quality for a hot springs sanatorium, but hardly suitable for the manufacture of ice.

It costs more per ton to make poor ice than it does to make good ice, so the question of producing the best quality product should be of interest to every engineer and ice manufacturer.

What is the cause of poor ice? Assuming that the ice plant is in good operating condition and its different parts functioning properly, that the temperatures, pressures, circulation and agitation, are all as they should be, what is there in the water to prevent its freezing into perfect ice?

Calcium and Magnesium Compounds, with Iron and Organic Matter, Cause Discolored Ice

The objectionable impurities to be found—in varying quantities—in nearly all water supplies, are calcium, magnesium, and sodium (all of which may be in the form of carbonates or bicarbonates, sulphates, and chlorides) iron, alumina, suspended matter and organic matter.

Of the above, the carbonates and bicarbonates of lime and magnesium, the sulphates and chlorides of magnesium, the iron and the organic matter, are the most objectionable because when they are present even in small quantities they are the cause of objectionable deposit in the ice which may range in color anywhere from gray to a dark brown, depending on the kind and amount present.

The carbonates and bicarbonates of calcium and magnesium form gray, dirty-colored deposits in the ice and cause shattering at low-freezing temperature.

Iron oxide causes bad discoloration, and, if present with calcium or magnesium carbonate, stains the deposit, magnifying the actual amount present.

Alumina and silica show as a dirty and somewhat discolored sediment.

Suspended matter will cause deposit and discoloration, depending upon its nature.

The sulphates and chlorides of magnesium, while they concentrate mostly in the core and retard freezing, are also the cause of dirty greenish or grayish-colored streaks or spots in the ice, but they do not cause deposit.

Sodium sulphate, sodium chloride and sodium carbonate, together with the sulphates and chlorides of calcium and magnesium, concentrate for the greater part in the core, causing heavy white cores and, if present in sufficient quantities, will form an opaque white shell around the lower sides and bottom of the cake.

Treatment of the water with hydrated lime, in an efficient water-treating plant, will practically eliminate the calcium and magnesium carbonates, will entirely eliminate the iron, will greatly reduce the alumina and silica and, followed by filtration, will eliminate the suspended matter and organic matter.

The lime treatment will also change the magnesium sulphate to calcium sulphate and the magnesium chloride to calcium chloride, which are not so objectionable for the manufacture of raw water ice.

Reason for Use of Hydrated Lime

The reason why hydrated lime is used to remove the carbonates of lime and magnesium, which are the principal cause of the objectionable deposits in raw water ice, can be briefly explained as follows: Magnesium carbonate and calcium carbonate are soluble in pure water to the extent of about three grains per gallon. When present in greater quantities they are held in

solution by the presence of carbonic acid gas. If the carbonic acid gas is removed, any amount in excess of three grains will be precipitated. A common example of this is the kitchen tea-kettle. The scale that you will find there is the calcium and magnesium carbonates that have been precipitated from the water when the carbonic acid gas has been driven off by boiling.

Adding the proper quantity of hydrated lime to water will absorb the carbonic acid gas; the carbonates of calcium and magnesium which were in solution will then be precipitated, together with the lime that was added.

The hydrated lime also precipitates any iron held in solution and the precipitate or sludge formed by the lime treatment aids in the reduction of the alumina and silica present.

The use of soda ash to soften the water is rarely found in the treatment of water for the manufacture of raw water ice. The use of soda ash changes the sulphates and chlorides of calcium and magnesium to sodium sulphate and sodium chloride. However, as lime treatment changes the sulphates and chlorides of magnesium to calcium sulphate and calcium chloride, and as these salts are no more objectionable than the corresponding sodium sulphate and sodium chloride, no benefit is derived by the use of soda ash.

In freezing a block of ice, the ice first forms on the inner surface of the can and extends towards the center from all sides. During the freezing process the mineral salts in the water are continually being washed from the surface of the new ice by the circulation of the water produced by the air agitation. The freezing process continues under these conditions until the concentration of the mineral salts in the unfrozen portion becomes so great that some of the impurities precipitate, settle out and are frozen in the ice.

The core water must be pumped just before this point is reached and replaced with fresh water in order to prevent deposit. The time in which the core is pumped and the number of times necessary to pump a core depend entirely upon the amount and kinds of mineral matter in the water.

If the mineral content of the water is so high that this core pumping must be made when the block is one-half to two-thirds frozen, the concentration will again reach the critical point before the freezing process is completed, at which time a second and often a third core water removal is necessary if untreated water is used and elimination of deposit and discoloration is desired.

Several Core Removals Are Needed with Untreated Water

For example, when freezing a 400-lb. block of ice, which requires about 50 gal. of water, if the water contains 20 grains per gal. of calcium carbonate, there will be about 1000 grains, or about 2⅓ oz., of calcium carbonate in the can of unfrozen water. Assuming that about one grain per gal. will freeze in the ice, we find that when 34 gal. have been frozen that there will remain in the 16-gal. core a total of 966 grains, which will be equivalent to 60 grains per gal., and in order to prevent deposit, core removal will be necessary at this point.

The 16 gal. of fresh water replaced in the core would contain 320 grains of calcium carbonate, and when all but 5 gal. of this have been frozen, the core water would then contain 309 grains, or a concentration again of 60 grains per gal.

Replacing this core water with 5 gal. of fresh water which would contain 100 grains of calcium carbonate, the critical point would again be reached when about 1½ gal. remained unfrozen, so that to make deposit-free ice from an untreated water of this character three core water removals would be necessary.

Treatment of such a water with hydrated lime, in an efficient water treating plant, followed by sedimentation and filtration, would reduce the objectionable mineral content to about three grains per gal. or about 150 grains to each 400-lb. can of water. Allowing again for the one grain per gal. frozen in the ice during freezing, this treated water can be frozen until less than 2 gal. remain in the core before the concentration of 60 grains per gal. is reached.

Use of Treated Water Reduces Heat Consumption in Making Ice

A simple B.t.u. calculation is all that is necessary to prove the saving in refrigeration possible by the treatment of water for the manufacture of raw water ice. It requires the expenditure of one B.t.u. to reduce the temperature of one pound of water one degree Fahrenheit, and 144 B.t.u. to change one pound of water at 32 deg. into ice at 32 deg.

Assuming the incoming water to be 70 deg., and the water of the mineral content as noted above, it can be seen that, using untreated water and three core removals, it requires 50 + 16 + 5 + 1½ gal. or a total of 604 lb. of water to make a 400-lb. block of ice.

To reduce the temperature of each pound of water from 70 deg. to 32 deg., 38 B.t.u. are required, making a total of 22,960 B.t.u. necessary to bring the 604 lb. of water to freezing point, and an additional 57,600 B.t.u. will be required to change the 400 lb. of water into ice, a total of 80,560 B.t.u. having been expended to freeze a 400-lb. block of ice from untreated water.

With treated water only 52 gal. or 433 lb. of water would be used. This would require the expenditure of 16,454 B.t.u. to bring this amount of water to the freezing point, and with 57,600 B.t.u. needed to change the 400 lb. of water into ice, makes a total of 74,054 B.t.u. necessary to freeze a 400-lb. block of treated water. This difference of 6,506 B.t.u. means a saving in refrigeration, or an increase in the capacity of the plant, of about 8 per cent and would seem to prove conclusively that water treatment will pay a handsome return on the investment in any plant where bad water conditions prevail.

When the zeolite or exchange type of softener was developed, it was thought that this method would prove ideal for raw water ice making, as at that time the effect of soda in any form in water used for ice making was not thoroughly understood. It was found, however, that water treated by the zeolite method often produced ice of poorer quality than ice made from the same water untreated.

While zeolite treatment will remove all the calcium and magnesium salts, thus giving a water of practically

zero hardness as far as hardness is concerned, it replaces the calcium and magnesium with sodium. In other words, a water containing 20 grains of calcium carbonate will, after passing through a zeolite softener, contain about 22 grains of sodium carbonate. Likewise if the water contains sulphates and chlorides of calcium and magnesium the zeolite softener will change them to sodium sulphate and sodium chloride. The result is that with the zeolite softened water, the mineral content of the water will not be reduced and the ice will have heavy opaque cores and oftentimes heavy opaque shells around the lower sides and bottom of the cake. Furthermore, zeolite treatment has no effect on the iron, and it takes but a trace of iron to give objectionable color. Also it has no effect on the alumina and silica and a filter must be installed to remove the suspended matter because the zeolite softener does not always work satisfactorily with dirty water.

The quality of the available water supply should be the first subject to be investigated by the new ice plant manufacturer, as well as by the operators of the existing plants where first quality ice is not being produced. If it is decided that water treatment is necessary for the production of a first quality product, the selection of the water treating plant for this purpose should be based not on the price but by the results obtained from the equipment. Uniformity of treatment is essential when the treated water is to be used for making raw water ice. Every can of water placed in freezing tanks must be of the same character, if uniform ice is to be produced. The treating plant should be capable of maintaining a constant strength of chemical mixture at all times, the proportioning equipment should be accurate under all conditions of operation, the reaction and sedimentation tank should be properly proportioned so that efficient sedimentation will result, and a sand filter of proper design and size should be provided so that the last traces of precipitated matter can be removed and a uniformly treated, clear, sparkling water delivered at all times.

Inn Plant Helps Industrial Germany*

Output of Notable Hydro-Electric Development Important Factor in Fight to Regain Industrial Supremacy

AFTER FIVE YEARS' construction during which many technical and financial difficulties had to be overcome, the Innwerk, a hydro-electric plant on the River Inn near Toeging, Upper Bavaria, Germany, was recently placed in operation. The fall of the river between Jettenbach and Toeging is utilized as well as a dam at Jettenbach which raises the Inn water level about 21.3 ft. With a total capacity of about 98,600 hp. over 465 million kilowatt-hours will be produced here annually. The importance of this figure is apparent when it is known that the total annual output of all German electric plants during 1925 is estimated at about 11 billion kilowatt-hours.

*Abstract of an article in the VDI-Zeitschrift.

From the dam a concrete tunnel 12.5 mi. long carries the water to the power house. This tunnel ends in a basin 394 ft. wide at the crest of a natural elevation at Toeging, while a canal 1¼ mi. long carries the used water back from the tailrace to the River Inn.

Normally 10,600 cu. ft. of water per sec. at an average head of 103.3 ft. flows through a rectangular concrete forebay 342 ft. long, which shapes into a tube as it approaches the penstocks. Coarse and fine screens, cleaned by an electrically-operated traveling cleaner are located at this point slightly ahead of the penstock valves. These valves can be closed in 16 sec. by one of three methods, by hand, by automatic controls functioning in case a break in the pipe occurs, or by re-

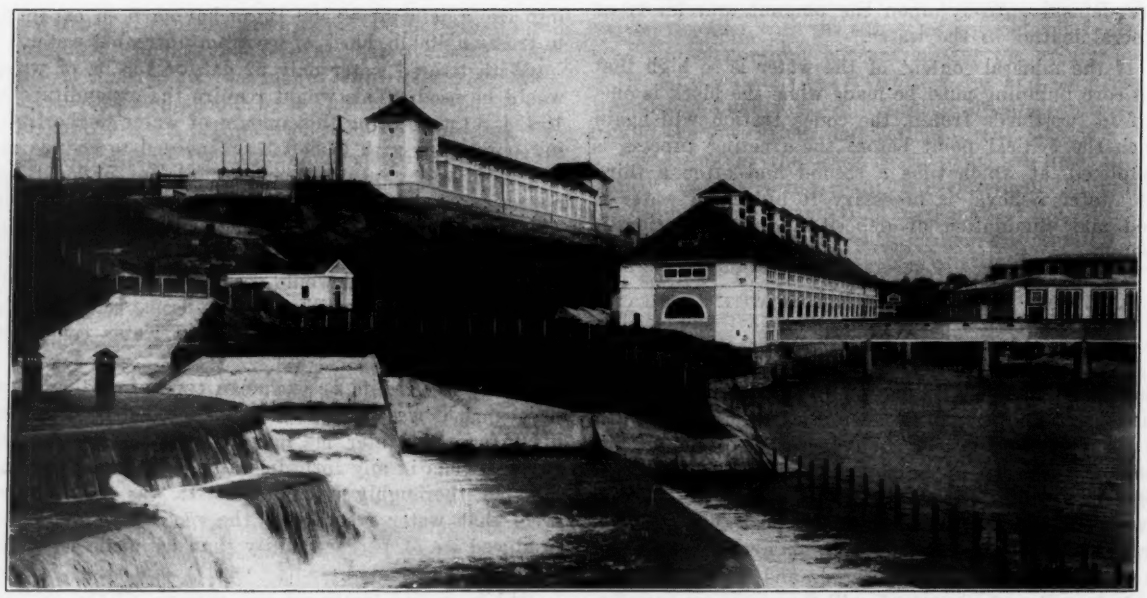


FIG. 1. GENERAL VIEW OF DEVELOPMENT, WITH SPILLWAY AND TAILRACE IN FOREGROUND

mote electric control from the plant. An oil dash pot retards the drop of the gates to prevent waterhammer.

From the forebay water flows through individual penstocks made of ½-in. Siemens-Martin steel plate, 13 ft. in diameter and 184 ft. long to the 15 main water turbines and one exciter unit. The guaranteed capacity of each unit is 9495 hp. at 103.3 ft. head and 1000 sec. ft. flow. The maximum capacity sometimes attained is 10,451 hp. at 111.5 ft. head.

Turbines are of the cased type employing single, flat curved bladed, reaction runners with inlet parallel to the shaft. The nickel steel generator shaft is 26 in. in diameter and a single disk pressure bearing of the Mitchell type takes up the horizontal thrust which sometimes amounts to as much as 33 t. All generators are built uniformly so that parts may be easily interchanged if necessary.

Seven d.c. units at the Inn Plant each produce 5775 to 6375 kw., 385 to 425 v. and 15,000 amp. Because of the high voltage, each generator has a double set of collectors, each with sub-collectors. This precludes a change in structure due to heat effects and mechanical stress even under highest loads. In continuous operation, the units operate as shunt generators with self-excitation although each generator may be excited by a 400-v. generator driven by the exciting turbine.

Eight completely encased three-phase a.c. generators develop 8200 kv.a. each at 214 r.p.m. Each a.c. generator has a direct-connected exciter of 92 kw. with field established by two machines located near the operating room. These generators are equipped with means for varying their voltage, thus regulating the exciting current and providing a centralized control of operating conditions for all a.c. generators at once. If the exciters should fail, the main generators may be excited by two reserve exciters, one operated directly from the exciter turbine, the other by a three-phase a.c. motor.

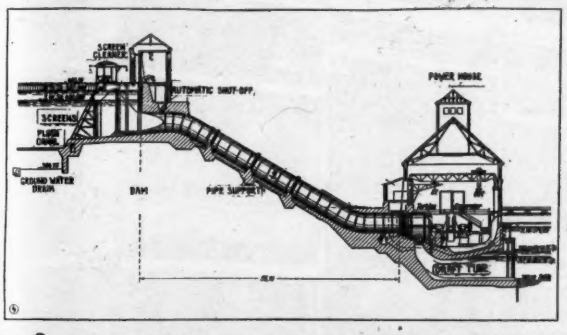


FIG. 2. CROSS SECTION OF FOREBAY, PENSTOCK AND POWER-HOUSE SHOWING ARRANGEMENT OF EQUIPMENT

Governor equipment is installed in a housing pressure-oiled and visible after removing the cover. The servomotor cylinder is built in at the bottom of the turbine and the actuating power is transmitted symmetrically to the regulating rings. Ventilating air from the generators is passed to the outside or to the power house for heat extraction.

Direct current from the Inn Plant is sent over aluminum wires to an aluminum plant where clay is melted in electric ovens, aluminum extracted and moulded into marketable bars in a nearby foundry. In a switching house the alternating current at 6000 v. is stepped up to 100,000 v. by means of two banks of transformers of 30,000 and 15,000 kv.a. capacity. This power is sent over two lines to the Hart carbide plant of the Bavarian power stations, where pure nitrogen is produced.

FIG. 3. INTERIOR OF TURBINE ROOM LOOKING FROM THE D.C. TOWARD THE A.C. UNITS

At times the river Inn carries much sharp sand, which is expected to cause wear on the surface exposed to the water, so the guide wheels are equipped with changeable case-hardened protecting plates. Where the exposure is greatest, the homogeneous steel guide paddles are specially hardened.

To assure quick, automatic and certain disposal of water during possible trouble in the Inn Plant, spillways were provided 3.7 mi. up the canal and at the dam. The former removes 4100 sec. ft. of water, the latter removes 3870 sec. ft., which may be increased to 5400 sec. ft. by means of three bottom vents.

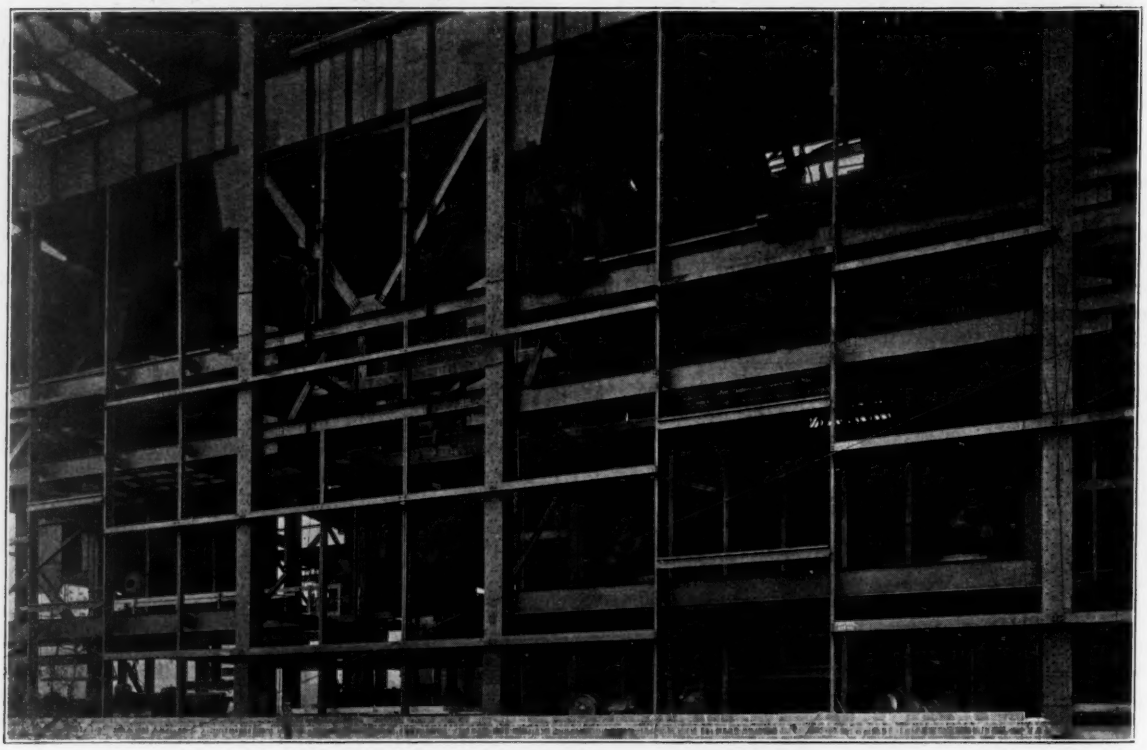
Our Consumption of Electricity

GREATER NEW YORK CITY consumed more than five billion kilowatt-hours of electrical energy last year, according to the New York Edison Co., which total is greater than the combined production of all the generating stations of Greece, Denmark, Latvia, Jugo-Slavia, Poland, Hungary, Norway, Sweden, Turkey, Roumania, Switzerland and the Netherlands. This comparison is made all the more interesting by the fact that in the countries named there are 12 times as many people as there are in New York City. In other words, New York City, with a population of less than 9,000,000 used more electricity than 109,000,000 Europeans. Indeed, the consumption of electricity in our metropolis is very nearly as great as the total for Great Britain, France or Italy.

Detroit Edison Co. Builds Beacon St. Heating Plant

FIRST UNIT OF NEW STEAM STATION DESIGNED TO SUPPLY DISTRICT HEATING SYSTEM, HAS CAPACITY OF 8300 B.HP.

TO KEEP PACE with the rapidly increasing demands on its district heating system, The Detroit Edison Co. is at present erecting a new boiler plant to be known as the Beacon Street heating plant, to supply steam to its extensive distribution system. This plant is located on Madison Avenue near Beaubien Street, Detroit, Mich. It is expected that the first section of it will be ready to operate by September 1, 1926. It will replace the Farmer Street station, the oldest of the four heating plants, which was abandoned at the close of the last heating season and will also take care of the future growth of the system for several years.



BEACON STREET HEATING PLANT UNDER CONSTRUCTION, SHOWING TYPE W BOILERS PARTLY ERECTED

The first section of the Beacon Street plant now under construction will contain two type W Stirling boilers, each of 4150-hp. capacity, designed for an operating pressure of 160-lb. gage. These boilers are to be fired by Taylor underfeed stokers, burning West Virginia and Kentucky coal.

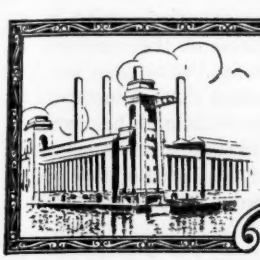
On account of the location of the plant, it is necessary to deliver coal to it by truck, as is the case with all of the Detroit heating plants. The trucks used for this purpose are of special construction with removable iron bodies having drop bottoms. These removable bodies filled with coal are lifted from the trucks at the Beacon Street plant by a mono-rail hoist, carried over the coal bunkers and the coal dumped through the drop bottoms into the bunkers.

To provide a convenient and economical method of ash removal, the boilers are set high and the ash hoppers can be discharged directly into ordinary dump trucks. Feed water is to be taken direct from the city mains and passed through a Cochrane open type deaerating feed water heater before going to the boiler feed pumps. The auxiliaries in this plant are both motor and steam-driven. Forced-draft and induced-draft fans will be motor driven, while the boiler feed pumps and the booster pump on the city water line will for the most part be driven by steam turbines.

STEAM CONTROL BY LONG-DISTANCE PRESSURE GAGES

Outgoing steam lines from the Beacon Street plant leave the building in a tunnel 60 ft. below the surface of the ground connecting with the present distribution system some distance away. The output of this plant will for a time be handled by a 16-in., high-pressure feeder in this tunnel and a 10-in. surface main. Pressure is maintained constant at the point where this feeder connects into the center of distribution several hundred feet away from the plant. The pressure at this junction point is indicated by long-distance, electrically-operated pressure gages on the control board and the operating engineer regulates the supply of steam according to readings of these pressure gages.

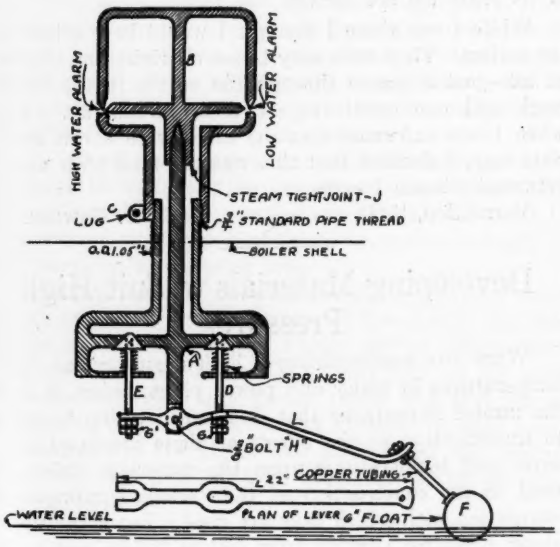
ALL DEAD WIRE should be considered alive, states G. E. Sanford of the National Safety Council, who further says that while electricity is the essence of life, too much of it is the essence of sure death.



LETTERS DIRECT FROM THE PLANT

High-Low Water Alarm Has Two Tones

In the accompanying sketch is shown a type of high-low water whistle installed on the boilers under my care. There are two distinct tones to each whistle, one for high water and the other for low. As shown, the main part of the whistle is cast in two parts, A and B. The shank of A is threaded with ¾-in. standard pipe thread and B is tapped the same size, but has a slot in one side and on each side of the slot is a lug, C, having a hole in it for a $\frac{5}{16}$-in. bolt. A hole is drilled and tapped through the top of the shell, between the manhole and main steam nozzle and part A screwed through from the inside. The thread on A is cut long enough so that it projects through about 2½ in. It is made of cast brass. Part B, made of cast iron, is then screwed onto A and when in the proper position the bolt through lugs C is tightened, locking it in place.



THIS HIGH-LOW WATER ALARM IS MADE IN TWO PARTS. THE WHISTLE CHAMBERS ARE FASTENED ON THE OUTSIDE OF THE BOILER SHELL WHILE THE VALVES AND THEIR ACTUATING LEVER ARE ON THE INSIDE

Valves D and E are operated by lever L and float F. The stems of these valves are screwed in and held in place by pins. Joint J is provided at the point where the upper part containing the high and low alarm sections is joined to the valve chamber and prevents the steam from blowing both whistles at the same time. Its shape is not arbitrary and may be made in any manner which will be steam tight.

I have witnessed the operation of these alarms for 18 yr. and, aside from a broken lever caused by a man cleaning the boiler, they never have failed or given any trouble. Their method of operation is as follows: When the water level goes down, the weight of the float and lever opens valve D and blows for low water. When the water level goes up, the float and lever swinging on bolt H opens valve E and blows for high water. By means of nuts G and G^1 the levels at which the whistles will blow can be changed to suit the operator.

Once having heard these whistles blow for high or low water, one never is in doubt as to the level for which they are blowing. The high side is of a lower pitch than the low, which has an ear-splitting, nerve-racking note. I never have been able to find out who made them and never have seen any such thing advertised in any trade journal. Besides those on the two boilers in my plant, there are only four others in this vicinity.

Minneapolis, Minn. FRED S. RUTLEDGE.

Corrosion of Steel Chimneys Affected by Design

In the writer's article under the above title appearing in the May 15 issue, p. 613, an example was given where, with one pound of fuel containing 5 per cent of free hydrogen, 0.45 lb. of water would result from burning it. The article then stated that "some of this water will condense at any temperature under 212 deg. F." In a recent letter, W. C. Stripe, of Pittsburgh, kindly called the writer's attention to the incorrectness of the statement quoted above. Of course, the condensing temperature (dew point) of water vapor in flue gas varies according to the percentage of water vapor present in the gas mixture.

Assuming 20 lb. of air used to burn each pound of fuel containing 5 per cent of available hydrogen, then there would be $0.45 \div 20 = 0.0225$ lb. of water vapor mixed with each pound of air used. To this should be added the moisture in the fuel and the original moisture in the air. We will assume that the fuel contained 3 per cent of moisture or $0.03 \div 20 = 0.0015$ lb. of water vapor per pound of air used. On a 100 per cent humid day in summer, with the thermometer at 90 deg. F., each pound of air also would contain 0.03103 lb. of water vapor. Adding the water vapor from these three separate sources: $0.02250 + 0.00150 + 0.03103$, we obtain 0.05503 lb. of water vapor per pound of air. This would be a saturated mixture at 107.6 deg. F., according to Kent, and at any temperature below this some moisture would condense out.

Now let us consider conditions on a cold day at 32 deg. F. when the relative humidity is only 40 per cent. Under such conditions each pound of air would contain

initially 0.00152 lb. of moisture and the total would be 0.02250 + 0.00150 + 0.00152 = 0.02552 lb. of moisture per pound of air. This would be a saturated mixture at 84.1 deg. F., according to Kent, and moisture would condense out at temperatures below it.

Both of these temperatures are much lower than the figure of 212 deg. erroneously referred to in the previous article and in most chimneys it is probable that condensation would occur only near the top of the chimney where such comparatively low temperatures might be expected, excepting under unusual weather conditions or where the fuel used has greater moisture-forming tendencies. In the above, no correction has been made for the oxygen of the air used to burn the hydrogen in the fuel, although this does not seriously affect the results obtained.

Montclair, N. J. CHARLES C. PHELPS.

This Plant Needs Competent Operators

WHY DO some employers place their heating and power plants in charge of men with qualifications little better than those of janitors? At one time I was sent to a power plant to find and remedy some trouble with a d.c. generator. I found the commutator had been worn down until many of the bars were entirely gone except where the metal was heavy, close to the armature end. Putting on a new commutator and testing it out, we started the engine (direct connection) and found that the crank was bent. Upon asking the engineer in charge of the plant what caused the bending of the crank he informed me that when he had started it up one day, the cylinder head blew off and he supposed the crank had been bent at that time.

Upon going over the pipe lines, I found that the trap on the receiver at this engine had been removed because it was in the way when sweeping and that he had also plugged up a drain valve in the exhaust line. This engine exhaust line extended 4 ft. above the cylinder at the heater and always was full of water. Further inquiry developed the fact that the two men running the plant had never had any more experience than firing a hard coal stove. They were paid eighty and seventy dollars a month and the manager was so pleased over how cheap he got them he could not think of anything else.

Investigation disclosed some expensive equipment, purchased by no one knew whom, such as damper regulators, numerous bronze valves, railroad unions, packing and diaphragm stock, still in the original boxes and yet there were more leaking unions and pipe fittings to the square inch in that plant than one could find holes in a sieve. A 36-in. pulley on a deep well pump was secured to the shaft by a few iron wedges and spikes driven in between the shaft and the pulley. When running it looked like a cross between a corkscrew and a roller coaster. They had much trouble in keeping the belt tight, in fact, spent most of their time on the belt (motor drive) and the motor would hop up and down on its foundation nearly the length of the foundation bolts (nuts were slacked off). The engineer said it was hard to keep oil in the motor bearings. I suggested that he place the motor and all in a tub so as to save the pieces as they rattled off.

Since they did not wish to go to the expense of straightening the crankshaft, we ran the engine as it was and managed to keep the brushes on the commutator in make-shift fashion by increasing the tension on the brush springs to the limit. I asked the engineer what he used to clean the commutator with and he brought me what looked at first glance like a cross-cut saw but really was only a rather coarse file. Instead, I got him some No. 00 sandpaper and fitted a block of wood for his use.

While talking to the manager, the subject of his engineer was brought up and I tried at least to tell him where a little improvement might be made. But no, far be it from such! That engineer was a good practical man and saved them from having to buy two new boilers by putting in three new tubes in one and five in the other. And taking me outside, I was shown a water cascade. Great quantities of hot water were flowing down a screen arrangement and what did not miss a wooden trough or was not blown away in spray found its way into the trough and to the suction of the feed pump. I was informed that this was a new money-saving device (?), that this water was return water from the vacuum return heating system pump, and the cooling was to condense the steam so the feed pump would not become too hot. This steam apparently was coming from the heating system and I decided was caused by radiator and drip traps leaking. But the engineer insisted that it had been a great saving in water as they had been compelled to waste it before on account of its being too hot for the feed pump.

While I was there I thought I would have a look at the boilers. They were easy to see all right—no trouble at all—just a glance through the cracks in the brickwork and one could inspect them thoroughly. And when I was informed that the tubes were blown every Saturday, I decided that this was the final blow and I returned whence I came.

Vermillion, S. D. L. A. COWLES.

Developing Materials to Suit High Pressures

WITH THE standardizing of high steam pressures and temperatures in boiler and power plant design, it is of the utmost importance that due consideration be given to investigation of the effects of these increased pressures and temperatures upon the materials which are used in the construction of the various equipment in connection with which they are used. For many years, steam pressures varying from 100 to 250 lb. per sq. in. were in general use for the generation of power; however, in the last few years designers have been increasing the steam pressures and temperatures of their plants by leaps and bounds so that now it is common practice to utilize pressures ranging around 350 and 400 lb. with superheated steam temperatures as high as 750 deg. F.

That extremely high temperatures materially changed the physical properties of many metals including cast iron, brasses and bronzes had long been known, but until a few years ago the deteriorating effect of a comparatively low temperature such as 600 deg. F. upon metals then commonly used for valves and fittings was largely a matter of dispute as few data on this point were available.

During the earlier years in which superheated steam came into use the erratic and unsatisfactory behavior of cast iron, brass and bronze equipment used in various parts of this and other countries has become generally recognized. Laboratory tests made during those years by a number of manufacturers established the fact beyond doubt that cast steel and high nickel alloys were most suitable for this work.

These tests indicated that cast iron subjected to superheated steam having a temperature of 400 deg. F. or higher, undergoes a slow, constant increase in volume with a consequent loss in strength. That this increase in volume of the iron goes on for a considerable length of time apparently was shown by a short laboratory test made upon some 6 by 12½-in. flanges which in 18 days had increased in diameter 0.019 in., or 0.0015 per cent, while a valve 22½ in. from face to face increased in length 5/16 in. in 4 yr., or 1.38 per cent.

As steel does not increase permanently in volume when subjected to temperatures of from 500 to 800 deg. F., it may be assumed that cast iron is so affected on account of the larger volume of elements, such as carbon and silicon, contained in that metal. It may be noted in this connection that cast iron is made up of approximately 92½ per cent iron and 7½ per cent of other elements by weight, but iron is so much heavier than carbon, silicon, sulphur or phosphorus, that when we consider a cube of cast iron by volume, we find that the elements other than iron, instead of occupying 7½ per cent of the cube, take up about 33 per cent, hence there is a large portion of cast iron which may be affected. Cast steel, on the other hand, contains a total of only 6/10 of one per cent of carbon, silicon, sulphur and phosphorus, an amount altogether too small to have an appreciable effect upon the total volume.

As stated, this increase in volume is followed by a decrease in strength, the loss in one case being fully 41 per cent from the assumed strength of the metal in the casting, or 49 per cent from the known strength of test bars cast at the same time.

Disintegration of the metal usually is shown by small cracks appearing on the surface of the casting, but this is not an infallible sign. Public service corporations long ago abandoned the use of cast iron on all lines subjected to highly superheated steam, and have standardized on cast steel valves and fittings. It goes without saying that the higher first cost of cast steel equipment over cast iron has been warranted by its satisfactory performance.

Los Angeles, Calif. C. C. BROWN.

Use of Tractors and Trailers in Power Line Construction

IN THE CONSTRUCTION of the 220,000-v. power line towers now under construction from Sacramento to Merced by the Great Western Power Company the use of the specially designed trailers shown in the accompanying photographs has increased the efficiency of erection.

Each trailer towed by a McCormick-Deering tractor hauls from 8 to 9 t. of steel, just enough for the erection of two 100-ft. steel towers, from the railroad to the spot where the tower is to be erected. As shown in the illustrations there is a partition down the center of the trailer which keeps the steel for the two towers separate. The steel for the towers is in lengths from 15 to 30 ft. The trailer bed is 15 ft. in length, but for the purpose of handling the 30 ft. sections there has been designed a unique removable extension as shown, consisting of a series of chains, pipe supports and stanchions. This extension adds an additional 8 ft. to the length of the bed when the extension is in place. The steel for the tower rests on three rollers and the sides of the bed are lined with sheet iron so that the steel can be pulled from the trailer by means

FIG. 1. TRACTOR AT LEFT PULLS STEEL OFF TRAILER

of a tractor. Two of these trailers are used on the project, each trailer towed by a tractor. A third tractor is used in pulling the steel from the rear of the trailers. When ready to unload, the end of the chain attached to the stanchion is removed from the stanchion, which permits the extension to drop to the ground. Then a chain or cable is attached to the end of the load of steel and the tractor pulls it off.

These trailers were built with removable side boards so that the trailers could also be used in stringing the high tension wire. When used for this work, the sideboards are

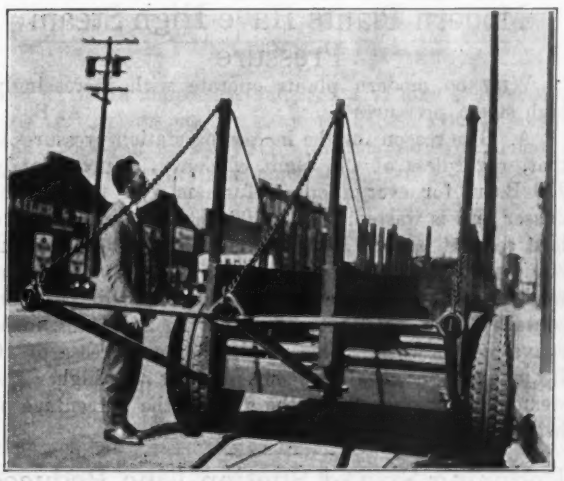
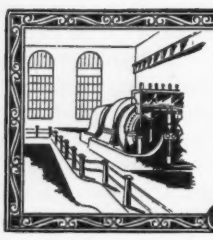


FIG. 2. REAR VIEW OF TRAILER SHOWING THE EXTENSION

removed and three reels of cable mounted on special brackets are loaded onto each trailer. As the tractor tows this load the high tension wire is reeled out along the route of the line, a method much more satisfactory than the usual method of pulling the wire from a stationary reel.

The three tractors will be equipped with power winches after the towers have all been erected, and will be used in raising wires to the insulators and stretching wires.

San Francisco, Calif. CHARLES W. GEIGER.



QUESTIONS AND ANSWERS

Vacuum Reduces Steam Consumption

How much does vacuum affect the steam consumption of an engine? My idea has been that an increase in vacuum affected the consumption at an equal rate, or directly proportional to a corresponding increase in the steam pressure. In other words, an engine doing the same work would consume an equal amount of steam at 150 lb. gage pressure, no back pressure, non-condensing, as it would consume at 150 lb. less atmospheric pressure with a perfect vacuum. J. H. B.

A. Losing the vacuum will almost double the steam consumption of an engine or turbine. If we assume a perfect engine (a really good engine will have a Rankine cycle efficiency of only about 70 per cent) with an initial pressure of 250 lb. gage and 100 deg. superheat, expanding down to a condenser pressure of ½ lb. per sq. in., the heat drop through the engine will be 1263 less 858 or 405 B.t.u. If the vacuum is lost and the engine exhausted to atmosphere at, say, 15 lb. pressure, the steam will be exhausted at a quality of about 89 per cent and a heat content of 1043 B.t.u. This is a heat drop of only 220 B.t.u. against 405 with the vacuum, so that it would be necessary to supply about 1.83 lb. of steam to do the work formerly accomplished by 1 lb.

Modern Plants Have High Steam Pressure

Why do modern plants operate with increasingly high steam pressures? A. B.

A. The reason for the increasing station pressures is that, regardless of the plant efficiency, approximately 950 B.t.u. for every pound of steam goes to the condenser and is wasted. With 100 lb. steam pressure the heat content is 1186 B.t.u. per pound. Subtracting the 950 loss to the condenser gives 236 B.t.u. available for work. If the steam were generated at 200 lb. it would contain 1198 B.t.u. per pound, leaving 248 B.t.u. to be converted to work. This results in an increase of 10 B.t.u. or about 4½ per cent, so that the higher the steam pressure generated the greater the percentage of heat which can be converted into work.

Reducing Size of Suction Line Reduces Load on Prime Mover

I could not refrain from passing a remark upon the centrifugal pump question under the above title in the May 15 issue, p. 617, as it almost parallels a case brought to my attention a few days ago. In fact, if J. B. didn't use brine in his system, I would think someone was trying to check up on me.

In the case which I mentioned the trouble was caused by the engineer himself allowing liberal values for pipe friction and then doubling them to be safe. The head was low anyway so when the pump was put in service taking its suction from a tank with other pumps, the pipe friction was much less than he estimated and in addition there was a small head on the suction which had not been considered. The total head was practically nil and the capacity about 75 per cent greater than expected.

Now a good pump will be so designed that the motor cannot be overloaded even at free discharge, in fact the free discharge power will often be lower than the regular operating power, but in these cheap little pumps, usually with single suction, the power keeps right on increasing with the capacity and will overload the motor. That was what happened, and a few turns on the valve in the discharge line fixed things fine by boosting the head and decreasing the capacity.

Evidently this was the engineer's mistake as the pump had been ordered for specific conditions. Ordinarily a careful salesman wil check up on such points even for the most careful engineer, but occasionally in a press of work a little one will slip by and turn up like a bad penny in the future.

In J. B.'s case I believe that there is another factor concerned. This is the specific gravity of the brine due to the heavy overload. I don't know anything about refrigeration although I believe that brine solutions in the smaller plants run from 1.2 to 1.25 in specific gravity. The horsepower when pumping brine will be greater than when pumping water being in the ratio of the densities. For this reason his trouble undoubtedly is caused by both over capacity and increased specific gravity or possibly the motor was figured a little close in the first case and the specific gravity neglected.

I am inclined to think that by throttling the discharge and increasing the head, the power requirements can be brought down to 5 hp., although this will depend entirely upon the pump characteristic. I have seen pumps tested that showed practically no variation in power between shutoff and full opening. Of course, as you say, the refrigeration requirements may not allow the reduction in capacity.

J. B. places the cart before the horse when he asks if the power can be reduced by "reducing the volume of brine and increasing the pressure" as the pressure is the independent variable. If you attempt to control the capacity without changing the head, either the pump won't handle it or cavitation will result in the eye of the impeller.

I believe you are right in saying there is not enough data to give a complete answer but, in view of my recent experience, I believe the two points covered above are what he is after. The only satisfactory answer is—Try it by throttling the discharge valve, you can't hurt the pump unless you run it some time with the discharge

completely closed. If the motor cools down and you still get sufficient brine, the matter is remedied. In any other event a new pump or motor will be advisable.

Bronxville, N. Y. B. MARKER.

Excess Air for Given CO_2 Depends on Available Hydrogen

WE ARE burning Illinois coal on underfeed stokers with an average of about 12 per cent CO_2. What is the per cent of excess air? C. B.

A. There is not sufficient information to answer this question in exact figures. The amount of excess air corresponding to any given percentage of CO_2 is dependent on the available hydrogen in the fuel. For this reason, authors of various handbooks and articles on combustion often make serious errors in publishing curves or formulas for determining excess air without specifying the fuel to which they are applicable. Any single curve showing varying amounts of excess air with variations in CO_2 can be applicable only to one fuel having a definite amount of hydrogen and carbon. This, in turn, determines the maximum CO_2 obtainable with no excess air.

Before using any curve showing the relation between CO_2 and excess air, even though extreme accuracy is not required, one should be careful always to consider at least the class of fuel burned. In the accompanying figure is shown curves for representative classes of fuel. Separate analysis of any fuel in each of the classes shown may show some variation from the values given but in general these curves will give approximate results.

In examining a CO_2—excess air curve, if the author has failed to indicate properly the class of fuel to which it applies, the engineer intending to use the curve should note the CO_2 value at the end of the curve, corresponding to zero excess air. Immediately, this will indicate in a general way the class of fuel to which it belongs. If, for example, this value is found to be 20.9, it safely may be assumed that the curve is for pure carbon and should not be used for ordinary fuels. Again, if this value corresponding to zero excess air gives 15 to 16 per cent CO_2, then it may be assumed that the curve is for a fuel, generally fuel oil, having between 11 and 14 per cent available hydrogen.

In the following table is shown the maximum CO_2 obtainable with different classes of fuels:

ULTIMATE ANALYSES OF REPRESENTATIVE FUELS
"DRY BASIS"

	Carbon	Hydrogen	Maximum CO_2
Coke Breeze	91.2	1.2	20.7
Lignite	73.2	5.1	19.3
Sub. Bit.	76.4	5.5	18.9
Eastern Bit.	84.9	5.1	18.8
Mid-West Bit.	62.0	5.5	18.4
Fuel Oil	84.0	12.7	15.5
Natural gas	73.6	24.6	11.7

If exact figures are required for any solid or liquid fuel containing hydrogen, the excess air may be determined by either of two equations:

$$E = \frac{O_2}{0.264\ N_2 - O_2} \qquad (1)$$

$$E = \left[\frac{N_2}{N_2 - 3.78\ O_2}\right] - 1.00 \qquad (2)$$

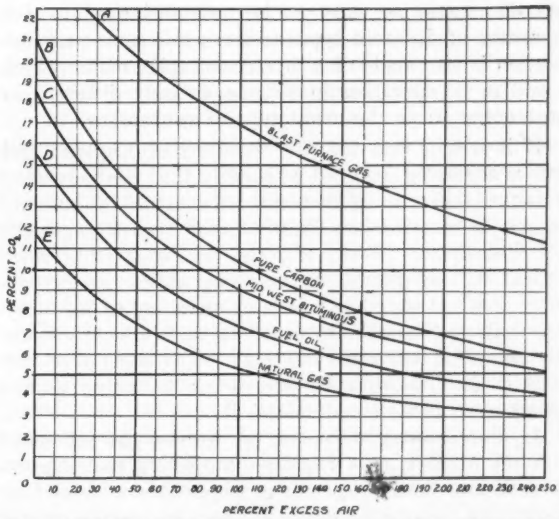
where, E = per cent of excess air, O_2 = per cent of oxygen in flue gas, N_2 = per cent of nitrogen in flue gas.

In the problem as given at the beginning of this article, if we assume 7.3 per cent O_2, the nitrogen will be 80.7 per cent and then, according to either equation (1) or (2), the amount of excess air will be 52 per cent.

To use the curves in the accompanying figure, or to interpolate between curves the theoretical maximum CO_2 must be known. The latter may be calculated from the equation:

$$CO_2 = \frac{20.9\ k}{20.9 - O_2} \qquad (3)$$

where, k = actual CO_2 in flue gas and O_2 is the oxygen.



FOR EXTREME ACCURACY, EXCESS AIR VALUES CORRESPONDING TO A GIVEN CO_2 IN EACH OF THESE CURVES APPLY ONLY TO A PARTICULAR FUEL ANALYSIS, BUT FOR APPROXIMATE CALCULATIONS ARE REPRESENTATIVE OF THE CLASS OF FUEL INDICATED

In the above problem, this works out to 18.4 per cent maximum CO_2. According to this, curve C should be used. This gives 52 per cent excess air and agrees with the results found by equations (1) and (2).

Low Cost Pump Repair by Welding

RECENTLY IN a New England plant a rotary pump that was badly needed was found broken when received. Two weeks would be required to get a new pump; the damaged one would have to be shipped back and a lot of bother and correspondence incurred to get credit for the broken one from the manufacturer or the railroad.

Bronze-welding, the manager knew, would make the casting as good as new. So it was welded. Two weeks delay saved; no packing and shipping; no bothersome correspondence; the total cost of the job, labor and materials was $1.46 which was less than the cost of the letter writing alone. Which proves that the best way is the one which gives greatest economy regardless of usual custom and tradition.

EDITORIAL COMMENT

Power Sources of the Future

In the Sunday supplement of a great chain of newspapers, a feature writer recently presented an article describing plans that are now being perfected in England and France for harnessing the tides to generate electric power, as the coal resources of those nations diminish. This writer states that in England three distinguished engineers of the Ministry of Transport are committed to the plan. In France, engineers and scientists of repute are said to be considering plans for apparatus of different types to serve this same purpose. Mention is also made of a mysterious solar motor which is said to be operating in France, entirely different in construction from the usual type of sun engine.

If it is true that the fuel resources of England and France are being depleted so rapidly that methods must be found for generating power other than by burning fuel, it is certain that English and French engineers will find them. Then, too, the possibility that some method will be found for releasing atomic energy directly does not sound as insane or visionary to the scientist as it does to the layman. If such a development ever comes, it will come suddenly. The thing that limits it is the limitation of our power to control atomic energy even if we could release it.

In this country, however, we are not as yet faced with the problem of a rapidly-diminishing coal supply. Nevertheless, the average non-engineer likes to think that every time he sees water in motion, thundering over a cliff in the form of a waterfall, or beating against a "stern and rock-bound coast" in the form of waves and tide, he is watching a tremendous waste of power. What he does not understand is that in most cases, the capital investment necessary to utilize these waterfalls or tides might be so great as to make the cost per unit of electric power ten or even fifty times its present price as generated from coal. At the present time there is in this country only one tide power project under way that seems to have sufficient merit to attract reputable engineers and financiers and even this project involves only the use of standard types of dams and hydro-electric generators.

Engineers in this country need have little fear that coal will cease to be our principal source of energy for a long time to come. In one way it is a good thing that the newspapers of the country are presenting to their readers more information on power. In another way, however, it is not so good because such articles are usually written for their spectacular value as news.

So it is well for the engineer, whose business is the burning of fuel to generate power, to keep himself informed on as many phases of the power problem as he can. He can assure his non-technical questioners that fuel will be our source of power for a long time. Meanwhile, if the English and French are forced to turn to tide power, regardless of the expense of it, we can be assured that they will work out the problem with their customary ingenuity.

Engineering Is Not a Stepping Stone to Something Higher

In speaking before a gathering of engineers some time ago, a successful manufacturer, an executive of considerable note in fact, advanced the idea of the engineer using his profession as a stepping stone to something higher—finance, for instance. "There is no reason," he said, "why an engineer should remain always an engineer. There is no reason why finance should not open up its avenues of opportunity to the engineer. I recommend that all of you engineers try for a little higher place than the *mere* engineering side of your profession."

"The mere engineering side of your profession!" Why the adjective? What is there so belittling about a profession which is responsible for all the advance, all the modern conveniences and comforts of civilization, all progress in our mental concept of the material universe, that a man should seek the earliest opportunity to sever his connection with it? True, in so far as concerns monetary return, engineering ranks with the lowest and in that respect finance holds opportunity but since when is it more to a man's credit to manipulate a few odd millions of dollars which, after all, no one really sees or can know much about, than it is to work out the exact calculations for a great bridge? Does it require a higher form of mental equipment to be a financier than it does to be an engineer? Are the decisions made by corporation executives or the weight deliberations of boards of directors behind closed conference doors, of greater importance to the world than the decision of an engineer to use molybdenum steel for the wrist pins of a flivver? If they are it cannot be proved.

It is true, without doubt, that many engineers make good executives, the finest type of executives, in fact, for the sense of responsibility and accuracy that goes with engineering is of great value to them, but the man who really is an engineer at heart, who takes profound interest in his profession, is not the man who would be greatly interested in the mere management of an organization.

By this we do not mean to imply that the engineer is any more altruistic nor that his regard for human welfare is any greater than the financier or executive. The engineer applies himself heart and soul to his problems, not because in so doing he thinks he can relieve humanity of some of its burdens but because of his selfish interest in them. The engineer is a curious animal. Like the scientist he is always prying into nature's secrets, not necessarily to better the world, but to satisfy his own curiosity. The designer of a 16-in., long-range

gun which is intended for wholesale human slaughter gets the same kick out of his job as does the discoverer of Salvarsan.

To an engineer, and by this is not meant the man who has merely spent four years in an engineering school because his proud parents, when he was a boy, judged his aptitude for the profession by his wizardry with the family alarm clock, but the man who in spite of all obstacles finds himself irresistibly drawn into the game, to such a man the dull activities of the financial executive would be the most tedious kind of drudgery. All the while he was supposed to be thinking up an excuse to float a new bond issue his thoughts would revert to the problem involved in overcoming the erosion of the blades of his latest 50,000-kw. turbine. It must be admitted that the standing of the engineering profession in America is decidedly low, a fact borne out by the remarks of the speaker, referred to in the beginning of this article. In Europe the condition is different. There, an engineer remains an engineer all his life. His profession is respected and he is regarded as a man of high intelligence, equal to, if not greater, than those in the legal or medical profession. In spite of the low relative standing of the engineer in this country, however, graduation into finance is not going to raise it. Engineering is not a stepping stone to anything else, as the speaker would have us believe. It is a profession worthy of a man's life work and one demanding not only the highest type of human intelligence but an inborn aptitude which cannot be acquired.

Are Instruments Used to Full Advantage?

In building an instrument, manufacturers have a definite point in view and there are very few instruments which will not give valuable data if they receive the proper care and attention.

If engineers would give as much attention to the use of the information they obtain as the manufacturers do to construction, there would be fewer instruments sold and those in service would pay a much higher average dividend.

The technical and semi-technical press has covered the field so thoroughly that few modern plants go in without a full complement of instruments and gages. Everybody assumes that such investments earn a big return, whereas beyond satisfying the engineer's curiosity, two-thirds of the industrial instruments so used are not only worthless but an actual expense to the plant. Draft, temperature, CO_2 and flowmeter charts are carefully changed, recorded or filed, as the case may be, and forgotten. Some are kept a week, some filed immediately in the waste basket and others go in a vault.

Data obtained directly are seldom of interest to anyone but the engineer but to be of value must be combined into a report and summarized weekly, monthly or yearly. Reports so obtained should answer two purposes; they should give in as much detail as necessary the distribution and cost of production of the output with reasons for fluctuation in unit costs, and they should give information necessary for keeping the power plant in step with other departments and useful for future design.

Unless reports and records fulfill these requirements, they are not up to standard and should be revised. Excepting, of course, instruments necessary for safe operation, no instrument should be purchased and installed until arrangement is made to use the information so obtained.

Turbines are not bought so that the engineer can satisfy his curiosity as to the number of kilowatts he can turn out in a day. Why should instruments, because they cost so little, be purchased to satisfy his vanity to have a distinctive row of charts hanging on the wall to impress visitors with the up-to-date features of his plant?

How Much Heat Can a Man Stand?

Some exceedingly interesting and highly valuable facts have been discovered with regard to human resistance and adaptability, by the U. S. Bureau of Mines and the U. S. Public Health Service, through the series of tests and experiments recently conducted in conjunction with the Society of Heating and Ventilating Engineers. The tests, made with human subjects, have proved of great value, not only in tearing down time honored but fallacious ideas and in scrapping traditional beliefs, but in forcing employers to the realization of the importance of atmospheric conditions. Because of the impossibility of collecting accurate and scientific data under actual operating conditions, the tests were made in laboratories and scientifically constructed test rooms which reproduced, exactly, the prevailing industrial conditions.

One of the outstanding facts developed was that a worker, stripped to the waist, could remain normal in every way and for an indefinite period of time, in a room where the heat was 90 deg. F. and with 100 per cent relative humidity, endurance under such conditions decreasing in proportion to activity or degree of labor.

Another fact brought out by these tests was that the consumption of large quantities of ice water by workers subjected to great heat, had no ill effects. In the tests conducted, several of the men drank as much as a quart of ice water in 15 min., after long exposure to high temperature and exertion and without any ill effects of any kind.

Conjunctivitis, an eye disease, common among industrial workers, was found to be caused by the entrance of perspiration into the eye. On a day when the eyes of the subjects were normal, a small quantity of sweat was dropped into the eye. Immediately the organ became inflamed and sore. Although the perspiration from the chest and arms was found to be more injurious than the sweat from the face or forehead, it is suggested that workers subjected to high heat have a sweat band to prevent sweat from falling into the eyes.

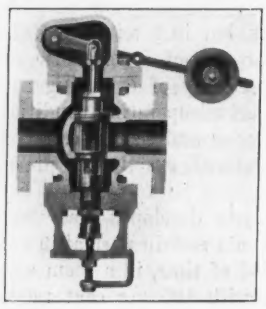
EVERY SALE in which there is misrepresentation is a black eye to the firm. That customer may come back, but when he comes back it's to get his money back and not to buy again. Repeat-sale customers are the best advertisement that anybody can buy; they save us hours and hours of sales-talk.

SAFETY PAYS! It's easy for workers to save money when they don't have to lose any time on account of accidents, says the National Safety Council.

POWER PLANT ENGINEERING DEVELOPMENTS AND NEWS

Feed Water Control Valve Has Adjustable Ports

AS AN improvement in the Copes feed water regulator, the Northern Equipment Co. of Erie, Pa., is offering the B.I.A. control valve which allows changes in flow areas from 0 to 100 per cent. For any given feed line size it will permit close boiler feed control by making changes in flow area to compensate for any increase or decrease in feed line pressure.



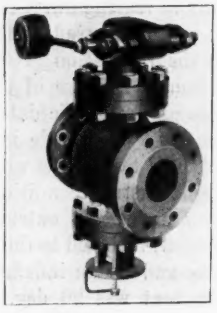


FIG. 1. THIS VALVE HAS ADJUSTABLE RECTANGULAR PORTS
FIG. 2. TWO STUFFING-BOXES ARE PROVIDED TO ELIMINATE UNBALANCED THRUST ON HORIZONTAL LEVER SHAFT

These changes can be made while the boiler is under load and permit the flow area to be checked by means of inflow and outflow charts so that the feed water control can be accurately adjusted under any conditions.

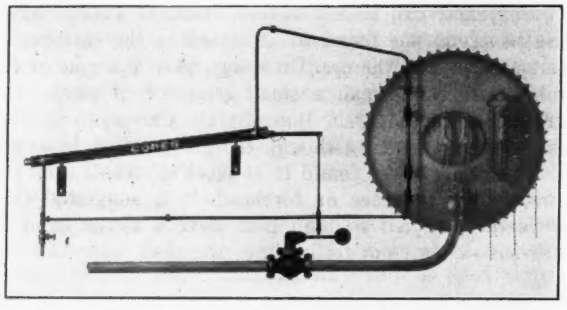


FIG. 3. THIS IS THE NEW METHOD OF COPES FEED WATER REGULATOR WHICH IS TO BE APPLIED TO THE NEW CONTROL VALVES

This new control valve differs from the type formerly furnished in a feed water regulator in that the ring seats are supplanted with a sleeve having rectangular ports as shown in Fig. 1. This sleeve is screwed into the valve body in place of the seats. The valve plunger also has rectangular ports of corresponding size to those in the sleeve. These adjustable ports are readily changed to accept the high excess water pressure which results from superheater and economizer losses existing in modern high-pressure boilers.

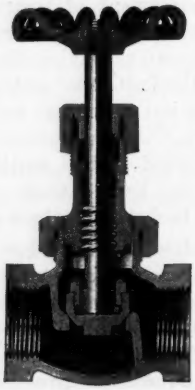
In operating, the plunger moves up and down but it can be rotated in relation to the sleeve so that the port area is increased or decreased. When the valve has been adjusted for the port area desired, the spindle is locked into position by a lock nut.

Another feature of this control valve is that it can be furnished with the double stuffing-box as shown in Fig. 2. By having the horizontal lever shaft extend through the two stuffing-boxes, this design eliminates any unbalanced thrust on the lever shaft, due to high pressures. The B.I.A. valve is suitable for all pressures up to 1200 lb.

This valve will be used in the new Type "R" feed water regulator shown in Fig. 3. The expansion member in this regulator is a heavy metal tube welded into a head and a heel piece which permits lineal expansion and contraction of the tube. This movement is transmitted at the upper end to a lever which multiplies and transmits it through a connecting strut to the control valve. The head and heel pieces of the regulator are mounted in heavy channel iron supports which fully protect them and the expansion tube from any chance of damage. The expansion tube of the Type "R" regulator always is in tension.

New Line of Valves Perfected

IN PLACING its new line of valves known as the Union Bonnet Regrinding Valve before the public, the Ohio Injector Co. of Wadsworth, O., announces a number of new developments.



CROSS SECTION OF THE VALVE SHOWING IMPORTANT FEATURES OF CONSTRUCTION

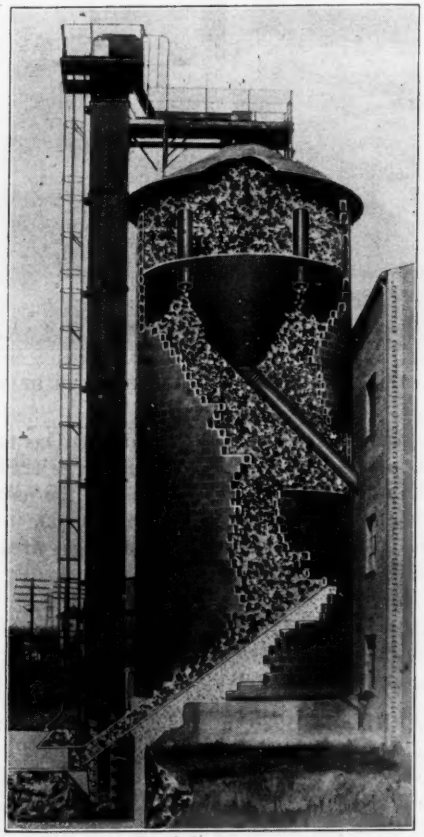
These valves have full pipe area at all points, full length pipe threads, ventilated non-heating hand wheels,

while the gland and stuffing box facilitates packing under pressure. The general construction of the valve is the result of a liberal factor of safety to prolong the life of the valve under all conditions.

Regrinding is easily accomplished without removing the valve from the line. A new construction which does not weaken the stem nor cut across the end surface of the stem is used to prevent excessive wear at this point and makes it impossible for the grinding pin to drop out when in use. Threads on the stem are protected by the two-piece bonnet construction made from a special composition used by this company for locomotive appliances. Valve disc is nickel bronze.

Patent Granted on New Storage Bin

COAL STORAGE, always a troublesome problem, continues to hold the attention of engineers and the Stearns Holotile Bin recently patented by the Stearns Conveyor Co. of Cleveland, O., offers some interesting features.



OVERFLOW FROM LIVE STORAGE BIN IS AGAIN DELIVERED TO THE ELEVATOR BOOT

Circular hollow tile construction reinforced with steel hoops give a strong but economical design. A live storage bin with spout and gate fills the upper part of the structure, the overflow falling by gravity to the lower section to be fed again to the boot of the elevator.

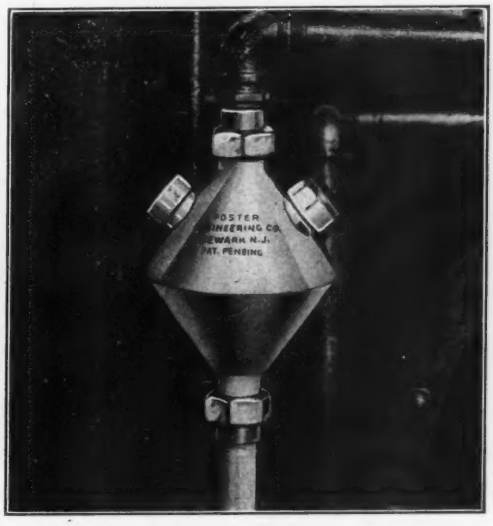
Elimination of dust, small temperature variation, protection from weather, low cost and large capacity per square foot of ground are some of the advantages listed. As the coal flows in a closed circuit no damage can result from leaving the elevator running after the live storage is filled.

Sight Flow Box for Circulating Fluids

IN MANY plants where oil or water is circulated for cooling purposes it is necessary that at all times the operator be able to see that the proper amount is passing through the lines.

Formerly, in most cases, this has been done with open funnels which often invited the dumping of refuse in the system. Also there was danger of overflowing if the pressure was increased.

To overcome these difficulties, The Foster Engineering Co. of Newark, N. J., is now placing on the market



THIS SIGHT FLOW BOX, EQUIPPED WITH GLASS COVERED OPENINGS, IS DESIGNED TO REPLACE OPEN FUNNELS IN OIL AND WATER COOLING LINES

a sight flow box as shown in the accompanying figure. By means of glass covered openings the fluid passing through is in sight at all times. These flow boxes are made for pipe sizes of ½ to 6 in.

ACCORDING TO THE LATEST REPORT of the Department of the Interior, compiled by the Geological Survey, the average daily production of electricity by public utility power plants in April, 1926, was about 7 per cent less than in March. The output for April, 5,784,532,000 kw-hr., was about 5 per cent less than the output for January. In 1925 the April output was about 7 per cent less than the January output, and in 1924 the April output was about 9 per cent less than that of January. The output for the first four months of this year was about 12 per cent larger than for the same months in 1925, and the output for the first four months of 1925 was about 6 per cent larger than that for the same months in 1924. These comparisons apparently indicate that industrial conditions so far this year are more satisfactory than in each of the two preceding years.

Construction Work Begins at Ohio River Falls

UNDER THE TERMS OF a license issued by the Federal Power Commission to the Louisville Hydro-Electric Co., a subsidiary of the Louisville Gas and Electric Co., construction of the nation's seventh largest hydro-electric plant has been started at Louisville. The initial capacity of the plant will be 108,000 hp., in eight units of 13,500 hp. each, with provision for an ultimate capacity of 135,000 hp.

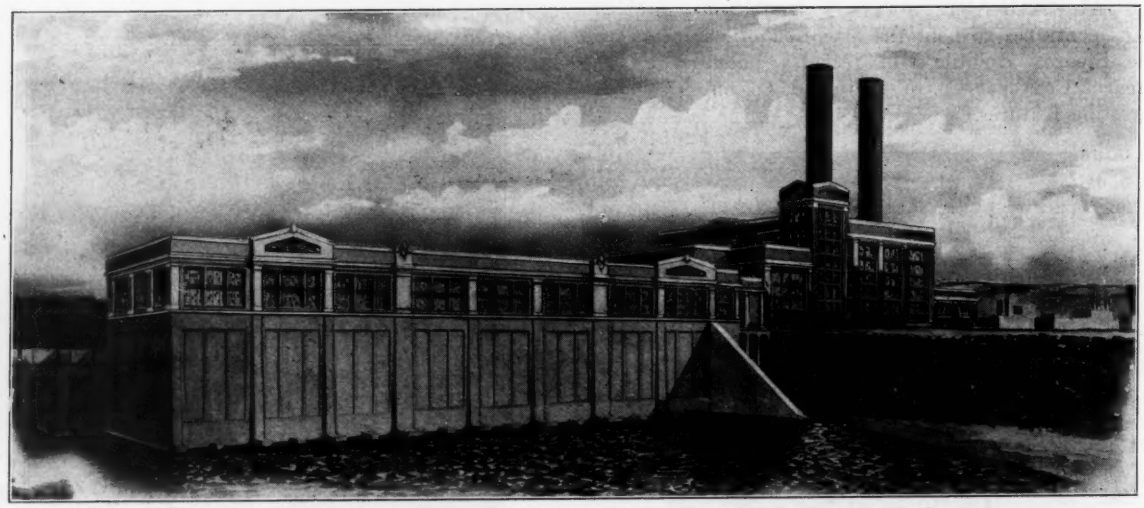
The development of power at the falls of the Ohio is made possible by the construction, by the Federal Government, of a dam 8650 ft. long, as part of the plan to establish a 9-ft. stage of water for navigation of the river from Pittsburgh to Cairo. The dam, at an approximate height of 20 ft., will be L-shaped, extending from the Indiana shore to Rock Island, which lies near what was formerly the historic old town of Shippingport, one of the earliest settlements at what is now Louisville.

The present development not only will provide more electric power for the homes and industries of Louisville, but it will improve navigation so that instead of the limited harbor space that Louisville now has, a great harborage for freight and passenger vessels will be created. Improved navigation has long been a topic of discussion; the completion of the Ohio Falls combined navigation and power development will make it a realized ideal.

Between Rock Island and the Kentucky shore a power house, 507 ft. long, will be constructed under the supervision of the Byllesby Engineering & Management Corp., engineers and managers for the Louisville Gas and Electric Co., at an estimated cost of $7,500,000. Byllesby Engineering & Management Corp. also has obtained the contract for construction of the Government dam at a cost of $2,056,187, a figure lower than the estimate of the Government's own engineers.

The Louisville Hydro-Electric Co. will pay the Federal Government an annual rental for use of the power to be developed by the dam. It is expected that a yearly average output of 357,000,000 kw-hr. will be obtained.

Electric power from the Ohio Falls development which is to be completed not later than early in 1929, will be distributed in Louisville by the Louisville Gas and Electric Co. Transmission lines will connect the Ohio Falls plant with the Louisville company's 125,000-hp. Waterside steam-electric station, in order that hydro and steam plant operation may be carried on most effectively. By 1929, however, it is expected that the electrical demands of Louisville and surrounding territory will have increased to a point where a large new steam plant will be necessary; therefore, plans have been made for the erection of a steam plant with an ultimate capacity of 250,000 hp., adjacent to the hydro power house at Shippingport, as shown in the accompanying illustration.



ARCHITECT'S DRAWING OF HYDRO PLANT AT OHIO RIVER FALLS; DESIGN PROVIDES FOR FUTURE STEAM STATION

The transmission system of Louisville Gas and Electric Co. is at present connected with large transmission networks in Kentucky and Indiana and the natural and transportation advantages of the city make it a dominant electrical production site for a great area extending in all directions.

Slight Explosion Occurs in Pulverizing Room at Columbia

ON APRIL 28, 1926, a slight explosion occurred in the pulverized coal room of Columbia Power Station, located at Columbia Park, Cincinnati, Ohio. The first indication of trouble was a somewhat minor explosion inside the conveyor that carried dried coal from the rotary dryers to the pulverizing mills, that blew open the observation doors on the conveyor. This was followed by a puff in the mill room, due to the igniting of coal dust that had been stirred up by the first explosion in the conveyor.

There was no damage to equipment, with the exception that a large steel rolling door in one end of the room, that was closed at the time, was slightly bulged. After a thorough inspection, the mills were started and

within a few hours operation was normal. Operation of the boiler room and other parts of the station was not interfered with.

One of the operators, who was standing directly opposite an observation door in the conveyor at the time of the explosion, had his clothes ignited by fire coming from the conveyor. This man died of burns the following day. Two other men were slightly singed about the face. They were working on different parts of the system and had taken covers off the conveyor to permit access.

The first cause of the accident has not been definitely determined. The most probable cause is that hot coal or hot ash from the dryer worked over into the conveyor. The conveyor does not normally contain an explosive mixture of air and coal. However, since the inspection door on one of the Fuller-Kinyon pump hoppers was open for maintenance work, an unusual amount of air was admitted to the conveyor, which caused an explosive mixture at this point.

Steps have been taken to prevent, if possible, a recurrence of the accident. Shut-off gates are being placed in the system so that any piece of equipment can be entirely shut off from the system for maintenance work. All observation doors are being clamped shut and additional vents supplied from the system to a point outside of the building.

The question of clean working clothes for the men has been forcibly brought to attention by this accident. Union overalls of non-inflammable fabric are to be worn by all men working in the coal preparation house and boiler room. The company will wash all overalls without charge and the usual type of cotton fabric overall will be impregnated after each washing to make it practically non-inflammable.

This power station has just been started and construction work, going on at the time, interfered with the proper cleanliness of the coal preparation house.

News Notes

AMERICAN ARCH CO., INC., New York, announces that it has taken over the business of the Waite & Davey Co. of Long Island City, N. Y., manufacturer of air cooled furnace blocks. All outstanding quotations will remain in effect and will be handled at the New York office by the existing sales organization of the Waite & Davey Co. in conjunction with that of the American Arch Co.

WESTERN ICE CO., Albuquerque, N. M., is now installing a Vilter 9 by 18-in. duplex compressor and a Vilter 9½ by 9½-in. single compressor, both to be driven by direct connected Ideal motors. It is also remodeling a 60-t. ice tank and installing a Shepard hoist with Gay type crane. This is a raw water ice plant, the Martocello drop tube system being used for agitation. Remodeling is in charge of Gay Engineering Corp., Los Angeles, Calif., C. R. Anderson, construction superintendent.

THE SIXTY AND TWO CONVENTION of salesmen and representatives of Jenkins Bros., manufacturers of valves and mechanical rubber goods, was held June 7 to 10 in commemoration of the 62nd year of Jenkins Brothers' business. The program included meetings at the executive offices in New York, trips through various factories of the company near by and a banquet at the Hotel Biltmore, New York.

THOMAS E. MURRAY, INC., New York, announces that all contracts have been awarded for the building and equipment of the new power plant for the Cannon Mfg. Co. at Kannapolis, N. C. All the plant equipment has been purchased direct from the manufacturers and will be erected under the supervision of the Murray engineers. The plant will contain three 620-hp. Walsh & Weidner boilers with Murray water wall furnaces and will have a maximum steam capacity of 181,800 lb. per hr. A 2500-kw. General Electric back pressure turbine will furnish part of the power to the mills. Brown-Harry & Co. of Gastonia, N. C., has contracts for the foundation and superstructure and the Virginia Bridge & Iron Co. for the structural steel. The plant will be in operation by the first of November, 1926, and is stated to be the most modern power plant in the textile industry. All engineering work on the project is by Thomas E. Murray, Inc.

R. H. BAKER COMPANY, INC. has removed its offices to the new Kendall Square Bldg., 238 Main St., Cambridge, Mass., and will continue its service on power plant and industrial piping from that location.

BRANCH SALES managers of the McClave-Brooks Co. from all parts of the country gathered at the Scranton Club recently for a conference and were favored with a special showing of the company's product at its Poplar Street plant. Among the exhibits were the stokers being built for the new Stevens Hotel in Chicago, seven of which will be installed in that plant.

E. J. BILLINGS of the Henry L. Doherty Co. has resigned to become vice president in charge of sales of the Fuller-Lehigh Co. He will assume his new duties July first, and will be located at Fullerton, Pa.

THE ENGINEERING WORK in connection with the design and construction of the new boiler plant of the National Enameling & Stamping Co. of Granite City, Ill., will be in charge of Baumes-McDevitt Co. of St. Louis, Mo. In this plant will be installed two Combustion Engineering Corp. steam generators, each having a capacity of 120,000 lb. per hr.

SLIGHTLY MORE than a year after he was awarded the Elliot Cresson Gold Medal by the Franklin Institute in recognition of his scientific achievements, Francis Hodgkinson, for many years Chief Engineer of the South Philadelphia Works, Westinghouse Electric and Manufacturing Co., was appointed Consulting Mechanical Engineer for the organization as a whole, taking effect immediately.

An official announcement to this effect was issued and signed jointly by H. T. Herr, Vice President in charge of the South Philadelphia Works, and W. S. Rugg, Vice President in charge of engineering.

Simultaneously an order, discontinuing the position of Chief Engineer of the South Philadelphia Works and creating instead the position of Manager of Engineering was announced. Appointed to the new position is A. D. Hunt, well known in engineering circles throughout the country and for many years a member of the engineering staffs of the Westinghouse organization.

THE EAST KOOTENAY POWER CO. of Fernie, B. C., has announced the immediate construction of an auxil-

iary steam plant at a cost of about $1,000,000 to meet the electrical demands of the Elk Valley and district. The company possesses hydro-electric plants at Bull River and Elko, B. C., from which Kimberley, Cranbrook, Coal Creek, Fernie, and the towns of the Crows Nest Pass are supplied with electric power. A. B. Sanborn of Fernie, resident manager of the company, states that the existing facilities have been found inadequate to meet the demand for electricity, especially in the winter time, when the rivers are frostbound, necessitating the erection of an auxiliary 5000-kw. steam plant at Fernie or Elko.

GEO. D. MASON & CO., Detroit, Michigan, is designing a new Masonic Temple building for Miami, Fla., estimated to cost approximately $2,000,000.

LOYALL A. OSBORNE, president of the Westinghouse Elec. International Co., was recently honored by election to the chairmanship of the National Industrial Conference Board. Mr. Osborne, a graduate of Cornell University in 1891, joined the Westinghouse organization after leaving college and, in 1902, was made vice president of the Westinghouse Elec. & Mfg. Co. He is now senior vice president of that organization. He succeeds Frederick P. Fish, of Fish, Richardson & Neave, Boston, as chairman of the Conference Board.

ADOPTION OF A simplified list of standard sizes and elimination of little-used sizes of wrought iron and wrought steel valves and pipe fittings were agreed upon at a recent conference with the Division of Simplified Practice, Department of Commerce, attended by manufacturers, distributors and users. The meeting agreed on standard sizes which brought about the elimination of 762 specified sizes of valves and fittings and 18 sizes of pipe.

Production, according to the standards agreed upon, will become effective September 1, 1926, but January 1, 1927 will be the effective date for spot stock. A standing committee to consider further needed revisions from time to time will be appointed.

GEO. H. KNUTSON, financial engineer, Chicago, Illinois, announces that he has purchased all the stock of the Carey Electric Light & Power Co. and the Carey Elec. & Milling Co., both of Wilmot, Wis. Mr. Knutson will act as president and treasurer; A. L. Gardner, Jr., as vice president, and A. Glad as secretary. Irving Carey will act as general manager at the office of the two companies at Wilmot.

THE PENNSYLVANIA POWER & LIGHT CO., Allentown, Pa., an interest of the Electric Bond & Share Co., New York, has concluded negotiations for the purchase of the Panther Valley Electric Co., Lansford, Pa. The company has also secured the Lehighton Electric Light & Power Co., Lehighton, Pa., operating a municipal power plant leased from the city.

THE INTERNATIONAL PAPER CO., New York, has announced plans for constructing a third hydro-electric plant on the Gatineau River, near Ottawa, Ont., the two others now being located at Chelsea and Farmers Rapids. It is planned to begin work on the project early next year; the other two plants being already under construction. Upon completion the output of the three stations will be close to 400,000 hp.

THE CITIZENS UTILITIES, Inc., a subsidiary of the Utilities Power & Light Co., Chicago, is completing negotiations for the purchase of the Derby Gas & Electric Co., Derby, Conn.

THE QUEBEC DEVELOPMENT CO., Quebec, Que., operated by the Aluminum Co. of America, Pittsburgh, Pa., through its Canadian subsidiary, is arranging for the immediate construction of a new hydro-electric power plant at Chute à Caron, Quebec, in the Lake St. John district in the northern part of the province. The station is estimated to cost in excess of $1,500,000, and will be used for power supply for the proposed aluminum plant to be constructed by the parent organization at Arvida, in this same section. William S. Lee is consulting engineer.

A. J. NOLDEN, for the past fifteen years chief engineer of the Schultz-Baujau Milling Co. of Beardstown, Illinois, has been appointed chief engineer of the Municipal Water & Light Plant of Bloomington, Illinois.

AT A RECENT MEETING, the Federal Power Commission, Washington, D. C., authorized the issuance of a license and preliminary permit to the Inland Power & Light Co., of Portland, Ore., for 50 yr. This covers a power project on the Clearwater River near Lewiston, Idaho, including the construction of a dam, power house and two transmission lines. The average static head at the power house will be 34 ft., the estimated power capacity 8500 hp., and the proposed ultimate installation will be 10,880 hp.

License was also issued to the Northwestern Power & Light Co., of San Francisco, Calif., for a project on the Elwha River in Washington, including a concrete-arch dam 195 ft. high, a tunnel 530 ft. long, a power house and transmission line. The head will be 186 ft. and the proposed ultimate installation is 16,550 hp.

LICENSE FOR 50 YR. has been issued by the Federal Power Commission to the town of Highlands, N. C., for a municipal hydro-electric power plant to have an ultimate capacity of 800 hp.

COPPUS ENGINEERING CORP. announces the resignation of Frans H. C. Coppus as president and treasurer of the corporation in order to devote his time to the railway equipment field, taking over the rights and interests of the corporation in this line. Mr. Coppus will act in a consulting capacity and remain as chairman of the Board of the Coppus Engineering Corp. Otto Wechsberg, formerly general manager, is president and general manager and Jerome P. George, Jr., is treasurer.

THE JERSEY CENTRAL POWER & LIGHT CO., Morristown, N. J., has under construction a new steam power plant at Whippany, N. J. The initial installation is to contain two 10,000-kw. turbo-generators, five 916-hp. boilers and auxiliaries. Boilers will be fired by chain grate stokers and complete automatic coal and ash-handling equipment will be installed. An outdoor power substation will be located near the power plant, transmission being at 33,000 v.

THE NORTHWESTERN POWER CORP., an interest of the New England Power Association, Worcester, Mass., has concluded negotiations for purchase of the system of the Oswego River Power Corp. and will operate in conjunction with associated companies at Buffalo, N. Y. The Oswego Company has begun the construction of a new transmission line from Oswego to Watertown, N. Y.,

and this will be completed by the new owner. Plans are also under way for a 110,000-v. line from Taylorville to South Colton.

THE PENNSYLVANIA-OHIO POWER & LIGHT Co. and the East Ohio Power & Light Co., both operating at Youngstown, O., have secured permission to consolidate properties and interests into a single company under the name of The Pennsylvania-Ohio Power & Light Co.

THE JOHNS HOPKINS UNIVERSITY, Baltimore, Md., has been granted an appropriation of $10,000 by the Engineering Foundation, New York, to conduct a two-year investigation in electrical insulation.

W. M. PERKINSON, Durant, Okla., a utility expert and former water superintendent for the city, has accepted an appointment as city manager at Lubbock, Tex., and will take up a residence at that place.

AT A MEETING of the board of directors of the Crocker-Wheeler Co., Ampere, N. J., the following officers were elected for the ensuing year: Edmund Lang, president; A. L. Doremus, vice president; H. C. Petty, vice president and secretary; T. S. Fuller, treasurer; G. W. Bower, assistant treasurer; and E. C. Jones, assistant secretary.

JOHN L. WEST has been appointed district manager of the Michigan Gas & Electric Co., at Hancock, Mich.

ELMER D. DUNNING, formerly vice president and general manager of the Dunning Compressor Co., Holmesburg, Philadelphia, Pa., has resigned to become head of the Lindley-Dunning Mfg. Co., Germantown, Philadelphia, manufacturer of pumps and kindred machinery.

SETH COHN, San Mateo, Cal., has been elected president of the Peninsula Electric Development League, operating in this district.

E. G. JONES, Marquette, Mich., has resigned as supervisor of gas plants in the Upper Peninsula for the Michigan Gas & Electric Co., to become general manager of the Lakeside Refrigeration Co., of the same city.

W. E. BANN, heretofore purchasing agent and auditor of the Texarkana, Tex., Division of the Southwestern Gas & Electric Co., has been appointed general manager of the division to succeed W. L. Wood, Jr., resigned.

AS A RESULT of activities of the Adirondack Power & Light Corp., Schenectady, N. Y., in connection with practical experiments in farm electrification work, a research council has been formed in this section to study and solve problems in this line, with a view to making the use of electricity for agricultural purposes thoroughly advantageous from different standpoints. Specific subjects will be assigned to each member and discussions will be carried out at each monthly meeting of the research work which shall have been conducted during the preceding month. The gatherings will be open for discussions and criticisms.

The council is composed of Prof. B. B. Robb, State College of Agriculture, Cornell University, Ithaca; C. H. B. Chapin, secretary, Empire Gas & Electric Co., Geneva; Charles H. Churchill, Jr., Adirondack Power & Light Corporation; L. C. Pickett, General Electric Co., Schenectady; H. C. Fuller, Utica Gas & Electric Co., Utica; and D. L. Renner, Westinghouse Electric & Mfg. Co., East Pittsburgh.

Catalog Notes

IN AN ATTRACTIVE folder, the Meriam Co., 8405 Detroit Ave., Cleveland, O., describes its new pulsation shock absorber adapted to relieve shock on pump governors, indicating and recording gages, damper regulators, centrifugal pumps, reciprocating pumps, flow meters and other locations where rapidly varying pressure impulses are encountered. It is made to work on pressures up to 5000 lb. a coiled pipe carrying the pressure to a chamber filled with liquid, from the top of which a straight pipe transmits the averaged pressure.

FROM FOOTE BROS. Gear & Machine Co., we have received an interesting and very complete catalog on the subject of gear problems and speed reducers. It is scheduled as General Catalog No. 200 and contains over 600 pages of information in regard to the use of speed reducers with different forms of gears, the application of such speed reducers to various power problems, a complete dimension list of speed reducers, spur and beveled gears, spiral, helical and herringbone gears and other special material used in gear driving. An interesting section on conveying machinery gives data in regard to the power required and conveying capacity for belt and spiral conveyors. Sprockets and chains is the subject of another section giving full dimensions of sprockets for both roller and built-up block chains. In the last hundred pages are given various engineering tables and data which will be found of convenience to the engineer dealing with power plant problems. The catalog is published by Foote Bros. Gear & Machine Co., 215 North Curtis St., Chicago, Ill.

THE NEW INDUCTO-THERM RELAY for use with motor starting switches is described in a leaflet just issued by Allen Bradley Co. of Milwaukee.

"BILLINGS DROP FORGED TOOLS" is the title of the 1926 catalog just issued by The Billings & Spencer Co., Hartford, Conn. This 36th edition of the catalog of mechanics' tools gives convenient wrench index tables with dimensions of wrench openings to fit standard nut and bolt sizes. One feature of the catalog is that new products are listed on colored pages and among these we find chrome-molybdenum tappet and check-nut wrenches, also chrome-molybdenum lifetime wrenches.

NATIONAL LAMP WORKS OF GENERAL ELECTRIC Co., Nela Park, Cleveland, Ohio, has just issued three extremely interesting bulletins entitled, "Safe Lighting for Dusty Industries," "New and Better Lamps," describing the new inside-frosted lamp, and "Printing Plant Lighting." These bulletins contain interesting illustrations of lighting application together with diagrams and many data of value to the illuminating engineer.

FROM THE International Nickel Co., 67 Wall St., New York, is received bulletin No. 4 on Making Steel Castings Stronger as accomplished by the use of nickel and chromium as alloys, also bulletin No. 5 on The Mill Inspection of Steel, describing and illustrating the various inspections at different points in manufacture, how they are made and defects for which watch is kept.

THE S. OBERMAYER Co. has issued a well-illustrated 28-page catalog describing Ramtite for the construction of one-piece monolithic furnace lining. The method of application of Ramtite is discussed and some interesting illustrations show workmen in the act of installing it, in various types of boiler furnaces.

RILEY STOKER CORP., Worcester, Mass., has just issued a new bulletin describing the Harrington Stoker, discussing the principles of design incorporated in it and showing, by means of interesting photographs, the details of construction and of installation for all types of boilers and various service conditions.

IRRIGATION by pumping is the subject of an illustrated booklet recently issued by the De Laval Steam Turbine Co. of Trenton, N. J. Not over one-tenth of the total arid land of the United States can be reclaimed by gravity irrigation, but many millions of acres can be brought under agriculture by pumping from rivers, lakes, canals, wells, underflows in valleys and from irrigated lands that have poor drainage and cheap electrical power with efficient centrifugal pumps is leading to the installation of great numbers of pumping equipments by individual owners. The pamphlet illustrates and describes numerous orchards and farms irrigated by pumping in the fruit-raising section of Oregon, including the Grants Pass District, where water is pumped for nearly 20,000 acres. It includes data on the selection of pumps to suit individual requirements, pump characteristics, pipe friction, speed and horsepower calculations, presented in simple form.

APPLICATIONS of indicating and recording instruments, pyrometers, thermometers, gages, tachometers and CO_2 recorders to power plants for both high-pressure, superheating, turbine-generator installations and moderate pressure engine installations are shown in an interesting way in a folder received from the Brown Instrument Co., 4465 Wayne Ave., Philadelphia, Pa., from whom copies of the folder or catalogs and information may be had by writing to that company.

HOMESTEAD VALVE MFG. CO. has just issued its catalog No. 33 dealing with the regular Homestead line of valves and describing the important changes which have been developed during the past year, one of the most important being a full round way valve, suitable for various services, which is made of acid-resisting metal, also semi-steel, with a lubricating device. Another development described is a combination Hovalco-Homestead blowoff valve of cast steel with monel metal parts for high boiler pressures. Another new product listed is the Homestead protected seat hydraulic operating valve with flanged connections.

IN AN interesting series of articles, published in pamphlet form by the Republic Flow Meters Co. of Chicago, Professor G. F. Gebhardt treats of Boiler Room Operation under the titles, Heat Losses, Air for Combustion, Heat Transmission in Steam Boilers, Boiler Efficiency, Preliminary Plant Survey, Results Achieved in Practice, Results from the Owner's Point of View and Results Not Achieved in Practice (in the small industrial plant).

The series can be obtained by writing to Republic Flow Meters Co., 2224 Diversey Parkway, Chicago, Ill.

DEAN HILL PUMP CO., Anderson, Ind., has just issued bulletin No. 203, giving dimensions, photographs and applications of horizontal single suction centrifugal pumps for various types of drives; and bulletin 1501, describing the reciprocating deep well pump heads for motor, belt or chain drive, together with tables of capacities and dimensions.

HILLS-MCCANNA NON FERROUS ALLOYS AND PRODUCTS are thoroughly described in a bulletin recently issued by Hills-McCanna Co., Chicago, Ill. After discussing some of the properties of Hills-McCanna alloys, the bulletin discusses some of the parts made from them, such as valves, plugs, fittings, thermometer wells and pyrometer protection tubes, drills, and so on. Brief mention is also made of the Hills-McCanna chemical pump and force feed lubricators.

"100 AND 1 WAYS TO SAVE MONEY" is the title of a new catalog recently issued by the Ingersoll-Rand Co. to show the many uses to which compressed air can be put in order to cut the cost of production. The field for portable air tools is being widened constantly and the Ingersoll-Rand Co., through many years' experience, has collected a great many actual records covering the operation of both tools and compressors. Many of these records are presented in the book, together with an unusually attractive assortment of photographs showing the various machines in actual service.

WESTINGHOUSE ELECTRIC AND MANUFACTURING CO. has just issued a 112-page publication describing the proper switching equipment for alternating current power stations. This special publication known as 1541-C deals with the general fundamentals that should be borne in mind when laying out a switchboard, and describes in detail the various types of switching equipment. It is profusely illustrated with diagrams and half-tone illustrations. The choice of switching equipment arrangement is well described, and with it are included switching devices and classes of stations of both the single bus and double bus systems. Safety enclosed switchboards are the subject of an interesting section, and the direct control switchboard for 2500 v. or less with oil circuit breakers and bus bars supported from the back, are explained in another section. The electrically operated switchboard material is particularly interesting and includes descriptions of panel boards, control desks, synchronizing devices and other data, including supervisory control equipment.

This publication may be had from any of the district offices or the Publicity Department of the Westinghouse Elec. and Mfg. Co., at East Pittsburgh, Pa.

IN A NEW 48-PAGE BULLETIN, the Cochrane Corp. discusses the general subject of Zeolite Water Softeners. The discussion takes up the chemistry of softening and the treatment of feed water with Zeolite; discusses the capacity of Zeolite softeners, and concludes with data on the selection of the proper softeners for various services.

APPLICATIONS of Gould's pumps to power plant uses —hot water heating, condenser cooling water, fuel oil supply, boiler feeding—are illustrated and described in a bulletin recently received from Gould's Pumps, Inc., Seneca Falls, N. Y.

Sparks from the Advertising Pages

Where Buyers and Sellers Meet

"Channels Through Which Minds of Men Are Inspired"

The words quoted above set forth the purpose of the publishing industry and of the men engaged in it.

In a great cathedral it is proposed to erect a memorial to the industry of which this publication is a part, and to the great army of people in it, whose life-work is to depict progress, gather and convey information and to stimulate thought by means of the printed page.

Just as fuel burns and the heat from it generates steam, which in turn flows through piping systems and is transformed into power for the service of mankind, so men give their life-energy to create ideas, to reduce these ideas to useful forms and to make them available to the service of all men.

Publications have grown, through civilization's greater needs, into plants for gathering thoughts, testing, proving and refining them.

Even in their function as channels of thought, in order to reduce waste, publications of the higher type are selective, each serving a particular group of minds to whom its particular product is of the greatest usefulness.

Power Plant Engineering has ever followed this highly specialized method for the reason that most useful and intensive service can be given only to men with common interests, problems and requirements.

Out of all the millions of people of this country, Power Plant Engineering serves the men in the power plant field. Out of the tens of thousands in the power plant field, it aims to make its service most vital and valuable to those engineers who are responsible for the design and operation of the most important and up-to-date plants.

In turn it is from such men that the ideas and experiences come which are printed in these pages.

From every part of the land men of sound judgment, extensive experience, creative intelligence and successful records contribute their ideas and thoughts.

Here this daily grist is sifted, weighed and verified. Then men of specialized ability and experience prepare for publication that which is of the most value.

In the operations back of these pages, words are looked upon as are bricks and steel and other materials to the builder, not to play with, nor to put together haphazardly, but to build an edifice that shall stand before the most critical minds and present both a fair and a true aspect of the subject and also assist the readers in building their own thought structures.

Such is the ideal back of the articles and advertisements in these pages.

An exacting business this, none more so; and one that calls for men of many types of mind, each specially educated and trained; a business that calls for all each man engaged in it can give of care, skill and mental effort.

For should this channel become filled up, or made tortuous, or the stream of thought be impeded, or muddled, by reason of lowered standards, careless methods or even undue errors, mechanical power and its great service to all industries and to all the people would become less efficient.

Conversely, each thought, idea, limit and method; each machine and piece of equipment, may inspire thousands of men, improve hundreds of plants and step up the rate of progress of the whole power plant field and of the industries and population it serves.

Machinery, Equipment and Supplies Used In The Production and Transmission of Power

Under the heading of each product listed will be found the names of the manufacturers of that product. The index to advertisers, next to the back cover, gives the page numbers on which the manufacturers' descriptive advertisements appear.

AIR COMPRESSORS.
Allis-Chalmers Mfg. Co., Milwaukee, Wis.
Bethlehem Shipbuilding Corp., Bethlehem, Pa.
Dean Bros. Co., Indianapolis.
De Laval Steam Turbine Co., Trenton, N. J.
Gardner Governor Co., The, Quincy, Ill.
Ingersoll-Rand Co., New York.
Murray Iron Works Co., Burlington, Iowa.
Nordberg Mfg. Co., Milwaukee.
Worthington Pump & Machinery Corp., New York, N. Y.
Yeomans Bros. Co., Chicago, Ill.

AIR FILTERS.
Cooling Tower Co., Inc., New York.

AIR WASHERS.
Badger & Sons Co., E. B., Boston, Mass.
Buffalo Forge Co., Buffalo.
Cooling Tower Co., Inc., The, New York.

ALARMS, HIGH AND LOW WATER.
Hills-McCanna Co., Chicago.
Huyette Co., Inc., The Paul B., Philadelphia, Pa.
Northern Equipment Co., Erie.
Reliance Gauge Column Co., Cleveland, Ohio.
Williams Gauge Co., The, Pittsburgh.
Wright-Austin Co., Detroit.

ARCHES, BOILER COMBUSTION.
Betson Plastic Fire Brick Co., Inc., Rome, N. Y.
Brady Conveyors Corp., Chicago.
Burke Engineering Co., Holland, Mich.
Detrick Co., M. H., Chicago.
Harbison - Walker Refractories Co., Pittsburgh, Pa.
Hofft Co., The M. A., Indianapolis, Ind.
McLeod & Henry Co., Troy, N. Y.
Obermayer Co., The S., Chicago.
Plibrico Jointless Firebrick Co., Chicago, Ill.
Queen's Run Refractories Co., Inc., Lock Haven, Pa.
Quigley Furnace Spec. Co., New York.

ASH AND COAL BINS.
Frederick Iron & Steel Co., Frederick, Md.

ASH BIN GATES AND DOORS.
Allen-Sherman-Hoff Co., The, Philadelphia, Pa.
Brady Conveyors Corp., Chicago.
Frederick Iron & Steel Co., Frederick, Md.
Hagan Co., George J., Pittsburgh.

ASH HANDLING SYSTEMS.
Allen-Sherman-Hoff Co., The, Philadelphia, Pa.
Brady Conveyors Corp., Chicago.
Conveyors Corp. of America, Chicago.
Detrick Co., M. H., Chicago.
Frederick Iron & Steel Co., Frederick, Md.
Hagan Co., George J., Pittsburgh.
Link-Belt Co., Chicago, Ill.
Stephens-Adamson Mfg. Co., Aurora, Ill.
Webster Mfg. Co., The, Chicago.

ASH TANKS.
Brady Conveyors Corp., Chicago.
Conveyors Corp. of America, Chicago.
Hagan Co., George J., Pittsburgh.

BEARING METAL.
Strong, Carlisle & Hammond Co., The, Cleveland, Ohio.

BEARINGS, ROLLER.
Timken Roller Bearing Co., The, Canton, Ohio.

BELT CONVEYORS.
Stephens-Adamson Mfg. Co., Aurora, Ill.
Webster Mfg. Co., The, Chicago.

BELT DRESSING.
Dixon Crucible Co., Jos., Jersey City, N. J.
Standard Oil Co., (Indiana), Chicago, Ill.
Stephenson Mfg. Co., Albany.

BELTING.
Goodyear Tire & Rubber Co., Inc., The, Akron, Ohio.
Quaker City Rubber Co., Phila.
United States Rubber Co., New York, N. Y.

BELTING, SILENT CHAIN.
Link-Belt Co., Chicago, Ill.
Morse Chain Co., Ithaca, N. Y.

BLOWERS, FAN AND FURNACE.
Air Preheater Corp., The, New York.
Buffalo Forge Co., Buffalo.
Coppus Engineering Corp., Worcester, Mass.
De Laval Steam Turbine Co., Trenton, N. J.
Ingersoll-Rand Co., New York.
Vulcan Soot Cleaner Co., Du Bois, Pa.
Webster, Howard J., Philadelphia, Pa.
Wing Mfg. Co., L. J., New York.

BLOWERS, FORCED DRAFT.
Sturtevant Co., B. F., Boston.

BLOWERS, PORTABLE.
Buffalo Forge Co., Buffalo.
Clements Mfg. Co., Chicago, Ill.
Sturtevant Co., B. F., Boston.

BLOWERS, TUBE.
Diamond Power Specialty Corp., Detroit.
Marion Mach., Fdry. & Supply Co., Marion, Ind.
Sherwood Mfg. Co., Buffalo.

BLOWERS, TURBINE.
Moore Steam Turbine Corp., Wellsville, N. Y.
Terry Steam Turbine Co., The, Hartford, Conn.
Wing Mfg. Co., L. J., New York.

BOILER BAFFLES.
Betson Plastic Fire Brick Co., Rome, N. Y.
McLeod & Henry Co., Troy, N. Y.
Quigley Furnace Spec. Co., New York.

BOILER CAP CLEANERS.
Lagonda Mfg. Co., Springfield, Ohio.

BOILER CASINGS.
Walsh & Weidner Boiler Co., The, Chattanooga.

BOILER COMPOUNDS.
Botfield Refractories Co., Philadelphia, Pa.
Dearborn Chemical Co., Chicago.
Hawk-Eye Compound Co., Blue Island, Ill.
McLeod & Henry Co., Troy, N. Y.
Paige & Jones Chem. Co., New York.

BOILER COMPOUND FEEDERS.
Hills-McCanna Co., Chicago, Ill.

BOILER FEEDWATER PURIFYING APPARATUS.
Griscom-Russell Co., New York.
Paige & Jones Chem. Co., New York.
Permutit Co., The, New York.
Power Plant Specialty Co., Chicago, Ill.
Scaife & Sons Co., Wm. B., Pittsburgh.

BOILER FRONTS.
McLeod & Henry Co., Troy, N. Y.

BOILER MOUNTINGS.
Lunkenheimer Co., Cincinnati.

BOILER SETTING CEMENT.
Betson Plastic Fire Brick Co., Rome, N. Y.
Botfield Refractories Co., Philadelphia, Pa.
General Refractories Co., Philadelphia, Pa.
Harbison - Walker Refractories Co., Pittsburgh, Pa.
Huyette Co., Inc., The Paul B., Philadelphia, Pa.
Obermayer Co., The S., Chicago.
Plibrico Jointless Firebrick Co., Chicago, Ill.
Queen's Run Refractories Co., Inc., Lock Haven, Pa.
Quigley Furnace Spec. Co., New York.

BOILER SETTINGS.
Betson Plastic Fire Brick Co., Rome, N. Y.
Botfield Refractories Co., Philadelphia, Pa.
General Refractories Co., Philadelphia, Pa.
Harbison - Walker Refractories Co., Pittsburgh, Pa.
McLeod & Henry Co., Troy, N. Y.
Obermayer Co., The S., Chicago.
Plibrico Jointless Firebrick Co., Chicago, Ill.
Queen's Run Refractories Co., Inc., Lock Haven, Pa.
Quigley Furnace Spec. Co., New York.
Walsh & Weidner Boiler Co., The, Chattanooga.
Webster, Howard J., Philadelphia, Pa.

To Find the Manufacturers' Advertisements of Products Listed Here, See Index Page 162

BOILER SKIMMERS.
Sims Co., The, Erie, Pa.

BOILER TUBE CLEANERS.
Lagonda Mfg. Co., Springfield, Ohio.
Liberty Mfg. Co., Pittsburgh.
Pierce Co., The Wm. B., Buffalo, N. Y.
Roto Co., The, Hartford, Conn.

BOILER TUBES.
Babcock & Wilcox Tube Co., The, Beaver Falls, Pa.
Bethlehem Steel Co., Inc., Bethlehem, Pa.
Murray Iron Works Co., Burlington, Iowa.
Scully Steel & Iron Co., Chicago.

BOILER WALL COATINGS.
Botfield Refractories Co., Philadelphia, Pa.

BOILERS.
Babcock & Wilcox Co., New York.
Badenhausen Corp., Cornwells Heights, Pa.
Bigelow Co., The, New Haven.
Brownell Co., The, Dayton, Ohio.
Casey-Hedges Co., The, Chattanooga, Tenn.
Edge Moor Iron Co., Edge Moor, Del.
Erie City Iron Works, Erie, Pa.
Freeman Mfg. Co., Racine, Wis.
Heine Boiler Co., St. Louis.
Kingsford Fdry. & Mach. Co., Oswego, N. Y.
Murray Iron Works Co., Burlington, Iowa.
Nuway Boiler & Engineering Co., Chicago.
Springfield Boiler Co., Springfield, Ill.
Union Iron Works, Erie, Pa.
Walsh & Weidner Boiler Co., The, Chattanooga.
Webster, Howard J., Philadelphia, Pa.
Wickes Boiler Co., The, Saginaw, Mich.

BOLTS AND NUTS.
International Nickel Co., New York, N. Y.

BREECHINGS.
Connery & Co., Inc., Philadelphia.
Littleford Bros., Cincnnati.

BRUSHES, DYNAMO & MOTOR.
Dixon Crucible Co., Jos., Jersey City, N. J.

BRUSHES, GRAPHITE.
Dixon Crucible Co., Jos., Jersey City, N. J.

BRUSHES, WIRE.
Pilley Pkg. & Flue Brush Mfg. Co., St. Louis, Mo.

BUCKET ELEVATORS.
Brady Conveyors Corp., Chicago.
Link-Belt Co., Chicago, Ill.
Webster Mfg. Co., The, Chicago.

BUCKETS, CLAM SHELL.
Orton Crane & Shovel Co., Chicago.

BUCKETS, COAL HANDLING.
Orton Crane & Shovel Co., Chicago.

CARRIERS, PIVOTED BUCKET.
Webster Mfg. Co., The, Chicago.

CASTINGS.
Bethlehem Steel Co., Inc., Bethlehem, Pa.
Erie City Iron Works, Erie, Pa.
Fuller-Lehigh Co., Fullerton, Pa.
Hills-McCanna Co., Chicago, Ill.
International Nickel Co., New York.
Neemes Fdry., Inc., Troy, N. Y.

CEMENT, FURNACE.
Betson Plastic Fire Brick Co., Rome, N. Y.
Botfield Refractories Co., Philadelphia, Pa.
General Refractories Co., Philadelphia, Pa.
Harbison - Walker Refractories Co., Pittsburgh, Pa.
McLeod & Henry Co., Troy, N. Y.
Obermayer Co., The S., Chicago.
Plibrico Jointless Firebrick Co., Chicago, Ill.
Queen's Run Refractories Co., Lock Haven, Pa.
Quigley Furnace Spec. Co., New York.

CEMENT GUNS.
Cement - Gun Co., Inc., The, Allentown, Pa.

CEMENT, HIGH TEMPERATURE.
Botfield Refractories Co., Philadelphia, Pa.
General Refractories Co., Philadelphia, Pa.
Harbison - Walker Refractories Co., Pittsburgh, Pa.
McLeod & Henry Co., Troy, N. Y.
Obermayer Co., The S., Chicago.
Plibrico Jointless Firebrick Co., Chicago, Ill.
Quigley Furnace Spec. Co., New York.

CEMENT, IRON.
Smooth-On Mfg. Co., Jersey City, N. J.

CHAIN WHEELS.
Babbitt Steam Specialty Co., New Bedford, Mass.

CHAINS, DRIVE.
Link-Belt Co., Chicago, Ill.
Morse Chain Co., Ithaca, N. Y.

CHIMNEYS.
American Chimney Corp., New York, N. Y.
Bigelow Co., The, New Haven.
Springfield Boiler Co., Springfield, Ill.

CLEANERS, BOILER TUBE.
General Specialty Co., The, Buffalo, N. Y.
Lagonda Mfg. Co., Springfield, Ohio.
Liberty Mfg. Co., Pittsburgh, Pa.
Pierce Co., The, Wm. B., Buffalo, N. Y.
Roto Co., The, Hartford, Conn.

CLEANING COMPOUNDS.
Dearborn Chemical Co., Chicago.

COAL AND ASH HANDLING MACHINERY.
Allen-Sherman-Hoff Co., The, Philadelphia, Pa.
Brady Conveyors Corp., Chicago.
Conveyors Corp. of Amer., Chicago.
Detrick Co., M. H., Chicago.
Fairbanks-Morse & Co., Chicago.